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Water Quality in Selected Canadian River Basins – St. Croix, St. Lawrence, Niagara, Souris and the Fraser Estuary

Edited by R.E. Kwiatkowski

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Contents

	Page
ABSTRACT	vii
RESUME	vii
INTRODUCTION	1
Suggested reading	2
THE RIVER BASIN NETWORK	2
Suggested reading	3
ST. CROIX RIVER	5
Suggested readings	9
ST. LAWRENCE RIVER	9
Suggested readings	19
NIAGARA RIVER	22
Suggested readings	31
SOURIS RIVER	32
Suggested readings	38
FRASER RIVER ESTUARY	38
Suggested readings	44
CONCLUSIONS	44
ACKNOWLEDGMENTS	46

Tables

1.	Balance of index relative to quality of aquatic life	18
2.	Relationship between the quality of aquatic life and water quality	18
3.	Water Quality Branch, Ontario Region activities on the Niagara River, 1975-1982	23

Illustrations

		Page
Figure 1.	River basin locations	4
Figure 2.	Sampling stations, St. Croix River, 1973-1977	5
Figure 3.	Seasonal distribution of dissolved oxygen for the St. Croix River, 1973-1977	8
Figure 4.	Seasonal distribution of dissolved oxygen for the St. Croix River, 1979-1985	8
Figure 5.	Distribution of population, St. Lawrence River, 1978.	10
Figure 6.	Water quality station locations, St. Lawrence River, 1977-1981	13
Figure 7.	Natural channelization of the St. Lawrence River	14
Figure 8.	Specific conductance zonation produced for the St. Lawrence River, 1977-1981	16
Figure 9.	Water quality conditions in the St. Lawrence River, 1978	20
Figure 10.	Sampling locations on the upper Niagara River, 1979	25
Figure 11.	Upper Niagara River mean total phosphorus concentrations, 1979	26
Figure 12.	Upper Niagara River mean total iron concentrations, 1979	26
Figure 13.	Upper Niagara River geometric mean total coliform concentration, 1979	26
Figure 14.	Monthly mean and 12-month moving average plot of chloride concentrations at Niagara-on-the-Lake	28
Figure 15.	Sampling locations on the Niagara River, May 1981, Trace Metal Survey	29
Figure 16.	Total iron concentrations in water of Niagara River, May 1981	30
Figure 17.	Distribution of total PCBs in bottom sediments of the Niagara River, May 1981	31
Figure 18.	Water quality monitoring stations, Souris River, April 1975 to October 1976	34

Illustrations (Cont.)

Page

Figure 19. Measurements of nitrogen, phosphorus, dissolved oxygen and total dissolved solids, Souris River, April 1975 to October 1976..... 36

Figure 20. Measurements of coliform bacteria and metals, Souris River, April 1975 to October 1976..... 37

Figure 21. Fraser River Estuary..... 39

Figure 22. Location of the main industries discharging to the Fraser River between 1970 and 1978..... 41

Figure 23. Location of storm sewer outfalls discharging to the Fraser River between 1970 and 1978..... 42

Figure 24. Tilbury Island, monthly means for fecal coliforms.... 43

Figure 25. Zones of impact resulting from the Iona STP discharge..... 44

Abstract

The business of the Water Quality Branch (WQB), Department of the Environment, is to provide information and advice on the quality of Canada's inland waters to managers, developers and the public, to ensure that this resource is wisely used. The Water Quality Branch conducts various monitoring programs to obtain data on the physical, chemical and biological characteristics within river basins. Identification of the causative factors and of the degree of variation of these characteristics within a water body is of paramount importance to any management program.

This report contains brief descriptions of the water quality problems existing in five Canadian river basins: the St. Croix, New Brunswick; the St. Lawrence, Quebec; the Niagara, Ontario; the Souris, Saskatchewan-Manitoba; and the Fraser Estuary, British Columbia. Analysis of monitoring data generated from intensive studies on these basins can be found in a variety of technical, scientific and governmental reports. This report, the first of a series outlining the work of the Water Quality Branch on various river basins across Canada, assembles the salient information obtained from these various reports in one document. For readers wishing to obtain further information on any of the river basins within this report, sources of information are identified at the end of each section.

Résumé

La Direction de la qualité des eaux (DQE) du ministère de l'Environnement a pour tâche de fournir des renseignements et des conseils sur la qualité des eaux intérieures du Canada aux gestionnaires, aux promoteurs et au grand public, afin d'assurer que cette ressource est judicieusement utilisée. La Direction de la qualité des eaux gère divers programmes de contrôle visant à recueillir des données sur les caractéristiques biologiques, chimiques et physiques des bassins hydrographiques. L'identification des facteurs déterminants et du degré de variation de ces caractéristiques dans un plan d'eau est d'une importance primordiale pour tout programme de gestion.

Le présent rapport contient de brèves descriptions des problèmes reliés à la qualité de l'eau dans cinq bassins hydrographiques canadiens: ceux de la rivière St. Croix, au Nouveau-Brunswick, du fleuve Saint-Laurent, au Québec, de la rivière Niagara, en Ontario, de la rivière Souris en Saskatchewan et au Manitoba, et de l'estuaire du fleuve Fraser, en Colombie-Britannique. Divers rapports techniques, scientifiques et gouvernementaux renferment l'analyse des données de contrôle provenant d'études approfondies portant sur ces bassins. Le présent rapport, le premier d'une série qui donne un aperçu du travail accompli par la Direction de la qualité des eaux relativement à divers bassins hydrographiques du Canada, rassemble en un seul document les principales informations contenues dans ces divers rapports. Les lecteurs désireux d'obtenir plus de renseignements sur les bassins hydrographiques dont traite le rapport pourront consulter les sources de renseignements indiquées à la fin de chaque section.

Water Quality in Selected Canadian River Basins — St. Croix, St. Lawrence, Niagara, Souris and the Fraser Estuary

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INTRODUCTION

Fresh water covers 756 000 km^2, or 7.6% of Canada's surface, and has had a profound influence in shaping the nation. Streamflow in Canada's rivers has been estimated to be about 100 000 $m^3 \cdot s^{-1}$, which represents about 9% of the total flow in all the world's rivers. Despite bountiful water resources, Canada is faced with serious local pollution problems, and difficulties are encountered in providing enough water of suitable quality to meet the competing demands for its use. There is no substitute for water. The survival of all forms of life depends upon an adequate supply of water of acceptable quality. A sound knowledge of the quality of the aquatic environment is essential to all levels of government for the management of present water uses and for the planning of future uses. Quality affects the suitability of water for human consumption, recreation, irrigation, livestock watering, industrial uses and aquatic life. In addition to describing the general health of Canada's water resources, water quality information identifies natural or man-made pollution sources and determines the adequacy of treatment methods or remedies to enhance or maintain water quality.

Although the management responsibilities for water are shared by the provinces and the federal government, it is incumbent on the federal government to provide leadership, particularly when addressing water quality on a national level. Within the federal government, the Department of the Environment plans and participates with the provinces in national and international water management programs in waters of federal interest, to achieve economic and social benefits for all Canadians while giving full consideration to environmental concerns.

The Water Quality Branch (WQB) of Environment Canada has been identified as the lead agency within the Department responsible for the development and implementation of a national monitoring network to assess the quality of the aquatic environment. This includes the identification of problem areas, gathering of data, research related to inland waters, and the planning and implementation of water programs and policies.

To fulfill this role, the WQB carries out monitoring programs, surveys and special studies at various locations across Canada. In 1982, the Cabinet provided the Department of the Environment with the authority and resources to negotiate federal-provincial monitoring agreements to implement efficiently a comprehensive water quality

network, to improve interjurisdictional assessments, and to address nationwide aquatic environmental concerns. The specific objectives of the Water Quality Branch Assessment Program are

(a) to determine changes and long-term trends in water quality
(b) to detect emerging problems on a local, regional and national scale
(c) to determine the effectiveness of regulatory actions related to legislative controls (e.g., phosphorus limitation in detergents, bans on the importation, use and manufacture of PCBs)
(d) to determine compliance with water quality objectives, where these have been implemented
(e) to determine the need for special (cause and effect) studies.

Once the agreements are in place, collection, analysis, archiving and dissemination of data from some 500 water quality stations in support of federal interests will occur, and a National Water Quality Assessment Program, capable of providing a national overview on water quality within provincial and federal jurisdiction, will be established.

For further information regarding the Water Quality Branch, Headquarters, contact:

Director, Water Quality Branch
Place Vincent Massey
Ottawa, Ontario
K1A 0E7

SUGGESTED READING

Water Quality Branch. 1985. The Business of the Water Quality Branch. Water Quality Branch, Inland Waters Directorate, Ottawa, 28 pp., ISBN 0-662-13727-2.

THE RIVER BASIN NETWORK

The term "pollution" has been universally accepted to describe or identify an undesirable state of any segment of the environment, whether it be air, water or soil. The consequences of water pollution are the deterioration of the water quality to the extent that it becomes unfit for the propagation of aquatic life or for other recognized uses of the water body. Surface water uses vary, and these uses require different levels of water quality. What constitutes acceptable water quality within a river basin is therefore dictated by the uses the water must support.

Any river is in constant receipt of materials from sources external to the river. The materials enter through natural paths such as tributary streams and land runoff, and through paths associated either directly or indirectly with man's activities (e.g., sewage treatment plants, runoff from urban areas, industrial inputs, etc.). Many of the materials entering the river will have a deleterious effect on the river ecosystem. Also, owing to the interrelationships between

pollutants, the characterization of the receiving water and the complex physical processes that occur within the river basin, the water quality exhibits a high degree of variability both in space and time. To determine the effect of development activities within a river basin and establish the degree of degradation in water quality from natural conditions requires thorough knowledge of the variation and interactions of the physical, chemical and biological properties of the river basin, both under natural and anthropogenically stressed systems.

The River Basin Network, one of two networks to be developed under each federal-provincial agreement, is designed to establish better understanding of the behaviour of the basin (interaction of the chemical, physical and biological components within it); to determine the sources and impacts of individual pollutants; to identify new and emerging water quality concerns; and to provide estimates of when and where water quality objectives are not being met.

Locations of sampling sites are chosen to represent the ambient water quality of the basin. Parameters to be measured at each station will be established based on issues of concern within the basin, as well as network and station classification. In a well-defined co-ordinated data-gathering program, there is a need to utilize the ecosystem approach. Parameter selection must reflect the linkages that exist between the water, sediment and biota for all pollutants of concern. Water and sediment provide a transport mechanism for the pollutants of concern, while living organisms integrate the effects of low concentrations over long periods of time and provide an excellent means of detecting many pollutants and noting their effects. One main objective of all environmental studies is to ensure the protection of the water for the most sensitive use; thus there is an inherent need to obtain information on the biotic component within each river basin.

The following sections describe five detailed studies done within various basins across Canada (Fig. 1). These studies typify the complex interactions of the physical, chemical and biological components within the aquatic ecosystem, which must be understood before natural variation within a given river basin can be separated from man's input.

The sampling locations, the parameter lists and the sampling frequencies were dictated by the issues of concern and the complexity of the basin (i.e., hydrologic, chemical and biological homogeneity, water demands and uses, and the existing and anticipated water problems). The ultimate objective in each basin network was to provide the basic information required for water quality management to ensure the optimum utilization of the water resource without significant degradation of the water quality.

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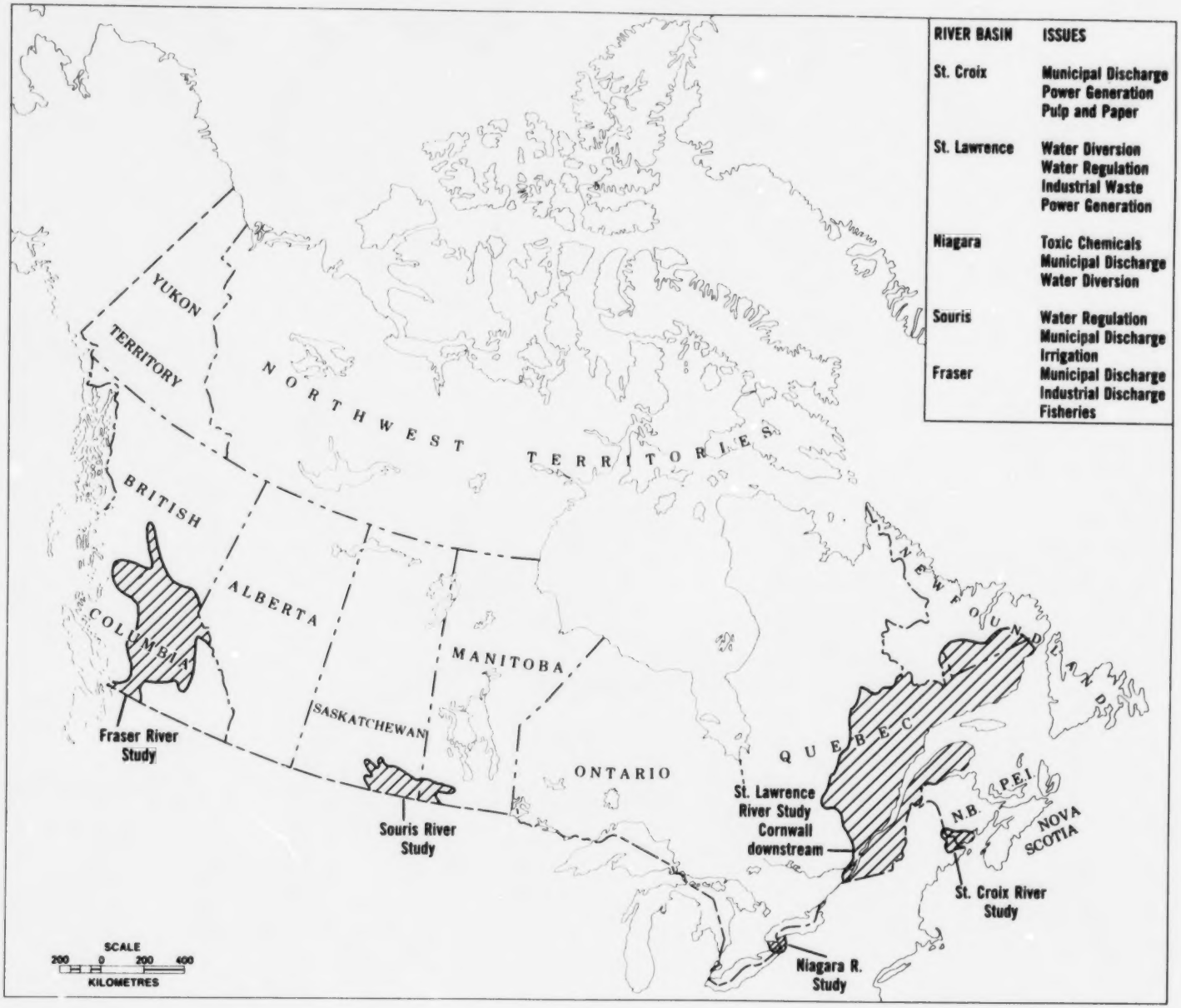

Figure 1. River basin locations.

ST. CROIX RIVER

The St. Croix River forms the International Boundary between Canada (New Brunswick) and the United States (Maine) and is approximately 124 km long (Fig. 1). The river drains much of York and Charlotte counties in New Brunswick, and Washington county in Maine. Although the upper 110 km of the river is considered to be pristine, the lower 14-km section between Woodland, Me., and Milltown, N.B., is of concern (Fig. 2). The Georgia-Pacific paper mill in Woodland, at the point where it discharges effluent into the river, marks the upstream end of the reach causing concern. The 14-km long section between Woodland and Milltown is sparsely inhabited, with settlements at Upper Mills, N.B., and Baring, Me., 9 km from the effluent discharge. The river banks throughout this stretch are generally heavily wooded, permitting limited access to the water. There are no major tributaries along the study reach, although three small streams - Strachan Brook, Mohammas Creek and Magurrewock River - enter the river below Upper Mills-Baring.

Figure 2. Sampling stations, St. Croix River, 1973-1977.

Flows as high as 529 $m^3 \cdot s^{-1}$ and as low as 17 $m^3 \cdot s^{-1}$ have been recorded in the study reach. Since 1975, the annual mean discharge at Baring has been 76 $m^3 \cdot s^{-1}$. Georgia-Pacific, which controls discharges in the study area, operated under a permit allowing a minimum discharge of 23 $m^3 \cdot s^{-1}$. Under non-spring flow conditions, the river width in the study area varies between 30 and 50 m and reaches depths of up to 4 m.

The river bottom is mainly gravel in the fast-flowing sections, with organic detritus accumulations in pools and protected areas. The major feature of the study area is a narrow, shallow channel beginning at Woodland and extending 5.5 km downstream. There are rapids (Bailey Rips) slightly more than halfway down this stretch. The river bends sharply after this channel and widens to include Haywood Island, where it becomes deeper and slower moving. The river narrows at Baring Rips for approximately 1.6 km, and drops 7 m in the area between Upper Mills and Baring. The river then widens into a slow-moving lake for approximately 3 km and finally narrows again until it reaches the downstream end of the study area at the Milltown International Bridge. Over the study reach, more than 30 islands divide the natural flow and form as many as three divided channels.

In 1966, the International Joint Commission established the Advisory Board on Pollution Control of the St. Croix River. This Board was given the responsibility for water quality monitoring and co-ordination of water quality planning activities in the St. Croix River Basin. To assist the Board in fulfilling its mandate, the Water Quality Branch (Environment Canada), in cooperation with the United States Geological Service and the Maine Department of Environmental Protection, monitored the St. Croix River for selected water quality parameters from 1966 to the present with the purpose of

(a) providing information on the impact of pulp mill waste on the water quality of the lower St. Croix River
(b) elucidating the effects of episodal events, as well as long-term trends
(c) relating water quality changes to remedial action taken by the Georgia Pacific Pulp Mill
(d) developing water quality objectives with particular reference to the passage of the Atlantic salmon (*Salmo salar*).

During the 1965-1966 period, the dominant major ion in the St. Croix River was sulphate. However, this changed in 1966, when the Georgia-Pacific pulp mill shifted from the sulphite to the kraft process. This resulted in a shift in ion dominance from sulphate to sodium and chloride. From the years 1966 to 1985, the overall major ion chemistry remained relatively constant. However, alterations to the pulping process did elicit some specific responses in water chemistry and the relationships between water quality parameters. During the period when untreated kraft effluent was discharged directly into the river (1967-1972), both the chemical composition and the discharge rate of the effluent were highly variable. This was reflected in poor water quality/quantity relationships. Although variability was reduced with the adoption of primary effluent treatment

in 1972, the most noticeable improvement corresponded to the adoption of a secondary treatment facility in 1977-1978. During the 1978-1985 period, there were good relationships between specific conductance and mean daily discharge as well as specific conductance and the major ions. In addition to regulating discharge rate and effluent composition, secondary treatment greatly improved the summer oxygen regime. Prior to 1978, summer oxygen minima were characteristically below 3.0 $mg \cdot L^{-1}$. However, secondary treatment lowered the river oxygen demand and improved the oxygen concentrations to levels near to the 5.0 $mg \cdot L^{-1}$ water quality objective for the St. Croix River.

By far the greatest change in water chemistry of the St. Croix River occurred during 1966, when the Georgia-Pacific Mill switched from a sulphite to a kraft process. In 1965 and early 1966, water chemistry at Milltown was characterized by high sulphate concentration and, to a lesser extent, elevated magnesium values. The shift to the kraft process and the establishment of the bleach plant had by the summer of 1966 reduced the concentrations of sulphate and magnesium in the river. However, concomitant with this, concentrations of sodium and chloride and to a lesser extent calcium and total alkalinity increased significantly. All of these major ions are employed in the kraft process. In addition to the shift in major ion composition, the kraft process was responsible for a significant increase in the specific conductance of the St. Croix River. Once the kraft process was initiated, there was little alteration in the overall major ion chemistry from the period 1966 to 1985. This is indicated by the relatively similar median values for the major ions. Modifications, to the kraft process, however, have led to changes in both the variability of the chemical composition of the kraft effluent and other water quality parameters.

During the five years from 1966 to 1972, the kraft effluent was discharged directly into the St. Croix River with no treatment. This was evident in the water quality at Milltown, which was highly variable and appeared to depend on fluctuations in the process at Georgia-Pacific. In most instances, the water quality of this period was Na^{+} and Cl^{-} dominated; it would, however, occasionally shift to Ca^{++} and HCO_3^{-} dominance. This was caused by an occasional flushing of the lime kiln and/or the colour removal system that was operational during 1969 to 1971. This variable chemical nature of the effluent was reflected by both the poor relationship between discharge and specific conductance and specific conductance and the major ions. During the next six years, from 1972 to 1978, the kraft effluent underwent primary treatment and clarification prior to discharge into the St. Croix River. Although the rate of effluent discharge was still variable as indicated by the poor discharge and specific conductance relationship, the chemical dominance was somewhat more stable. There were improved linear relationships between sodium and specific conductance and chloride and specific conductance. This was likely the result of increased residence time of effluent in the primary treatment facility, which permitted greater mixing of effluents from different phases of the kraft process. The data for the period 1978 to 1985 reflect the effluent quality after undergoing secondary treatment. This period is characterized by both a relatively constant effluent

discharge rate and chemical composition, as is indicated by good relationships between discharge and specific conductance and specific conductance and the major ions. Much of this appears to be the result of the 11-day retention of effluent in the aeration ponds of the secondary treatment facility. This serves to regulate not only the chemical composition of the effluent but also the rate of discharge.

In addition, the secondary waste treatment facility has resulted in considerable improvement in the summertime oxygen regime of the St. Croix River. During the six years (Fig. 3) of primary effluent treatment (1972-1978), summertime oxygen concentrations were characteristically low. In fact, the minimum value recorded was 1.2 $mg \cdot L^{-1}$, a value far below the water quality objective of 5.0 $mg \cdot L^{-1}$. The adoption of the secondary treatment facility reduced the suspended solid load and the BOD of the effluent and has thus served to improve summer oxygen concentrations considerably. The summertime oxygen concentrations during the 1978-1985 period (Fig. 4) were generally near or above the water quality objective. Not only does the improved oxygen regime have considerable biological importance, such as allowing the passage of Atlantic salmon, but it may also have some important chemical implications.

To assist management in understanding of the St. Croix ecosystem, a multiple regression equation was developed to predict the dissolved

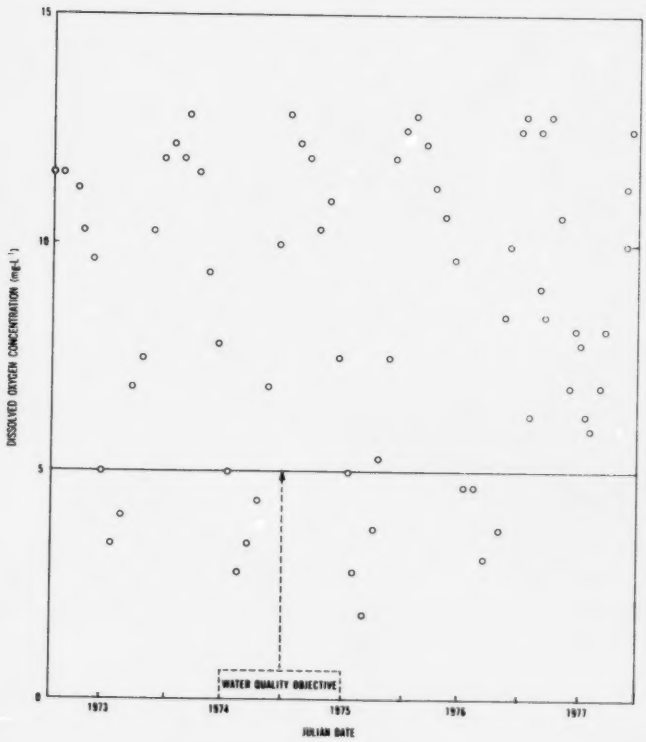

Figure 3. Seasonal distribution of dissolved oxygen for the St. Croix River, 1973-1977.

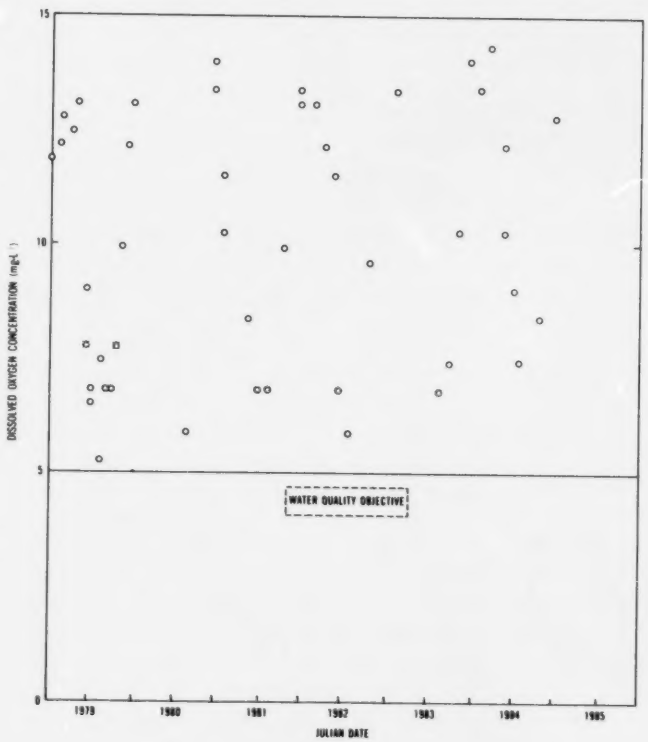

Figure 4. Seasonal distribution of dissolved oxygen for the St. Croix River, 1979-1985.

O_2 saturation at the Milltown site. Comparison of actual values obtained through sampling, with those predicted from the model, indicated that the model generally predicted slightly lower values than observed. However, the lower predicted values are desirable, as they correct for possible sampling errors on the side of the environment. Strict control of river discharge rates must be maintained to avoid episodal oxygen depletion.

For further information on the St. Croix River contact:

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ST. LAWRENCE RIVER

The St. Lawrence River (Fig. 1) is one of the major rivers of the world and is of prime importance to the people of Quebec. Its diversified biological resources, the numerous campsites and small craft harbours found along its banks, as well as the number and size of the municipalities it supplies with water, contribute to its environmental importance, just as municipal, agricultural and industrial statistics indicate its economic importance. It is both the domestic and industrial water source for numerous bordering municipalities, in particular Valleyfield, Montreal, Laval, Longueuil, Varennes, Sainte-Foy, Sillery, Lévis, Trois-Rivières and Lauzon. Biologically, the St. Lawrence is the richest and most diversified body of water in Quebec. Its natural vegetation constitutes a huge matrix which supports numerous organisms feeding an abundant fauna. The marsh and floodplain vegetation provides, among other things, food and shelter for fish, migratory birds and semi-aquatic organisms. These natural resources make it possible for a substantial part of the population of Quebec to participate in commercial and sporting activities. The maintenance of these resources is essential to their use.

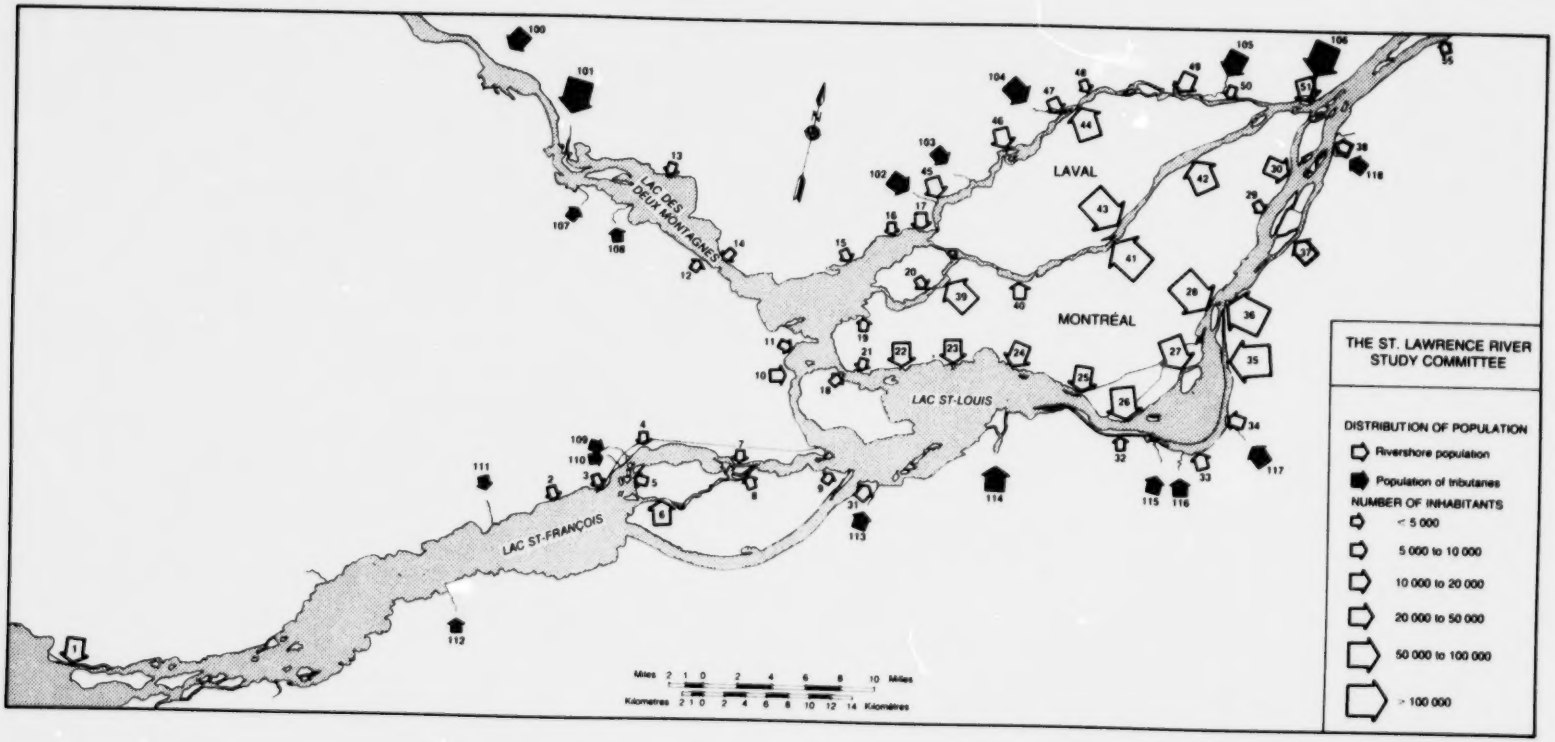

Figure 5. Distribution of population, St. Lawrence River, 1978.

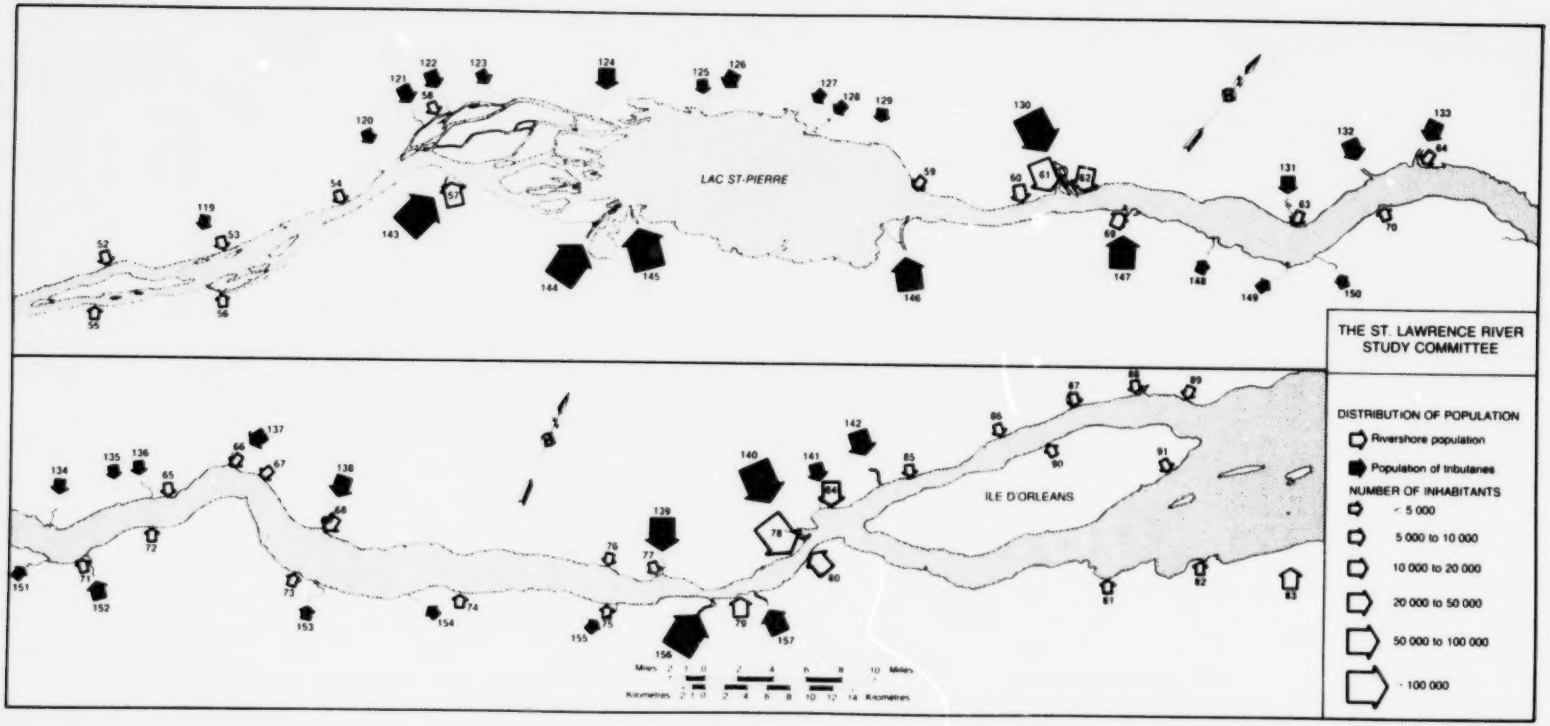

Figure 5. Continued.

In Canada, the "health" of the St. Lawrence River, which drains from one of the most developed hydrographic basins of the world (Fig. 5), is a subject of particular concern. More than 80% of the population of Quebec is concentrated in the St. Lawrence River Basin. The riparian population of approximately three million people is found in the two large urban centres of Montreal and Quebec City, as well as in many smaller cities along the shore of the river. There are also approximately two million people in the drainage basin of St. Lawrence tributaries. Most of the municipalities have sewer systems, but very few have sewage treatment, and therefore a major portion of waste water is discharged raw into the river and its tributaries.

In 1971, following an inventory carried out on the Great Lakes, the Canada-Quebec Consultative Committee on water problems set up a task force to review the available documents on the quality of the water in the St. Lawrence River and to develop programs for its management and use. In its report of July 1972, the task force underlined the importance of the St. Lawrence River for both recreational resources and fauna. While recognizing its needs for commercial and energy purposes, they pointed out the environmental impact from pollutants, such as the accumulation of mercury in fish, effects of hydrocarbons and toxic pollutants on migrating birds, dangers of bathing in water contaminated by sanitary disposal, and restrictions imposed on boating by the proliferation of aquatic plants.

Following the recommendations of the task force, an agreement was signed between Canada and Quebec, the terms of which were to carry out a biophysical inventory of the St. Lawrence River and to prepare a plan of action to halt its deterioration. The project was entrusted to the task force until 1973, and subsequently to the St. Lawrence River Committee, established according to the terms of the agreement. The objectives of the water quality monitoring program established by the Water Quality Branch as part of the agreement were

(1) to identify pollution problems, by
    (a) detecting areas affected by pollution (toxic substances, nutrients)
    (b) assessing the causes of pollution and determining the possible restrictions on uses of the aquatic environment;

(2) to establish baseline information, by
    (a) measuring the short-term (hydrological cycle) and long-term (trends) evolution of aquatic environment quality
    (b) assessing pollutant contributions to the ocean;

(3) to determine whether water quality objectives are attained, by
    (a) measuring water quality in critical areas;
    (b) analyzing and comparing measurements with the quality objectives set for the various uses of the aquatic environment.

The St. Lawrence River Network consisted of 46 stations located between Cornwall and Quebec City. The nine Lac Saint-François stations (across from Cornwall) were part of a special study to determine the pollution loads originating from the Great Lakes and the international

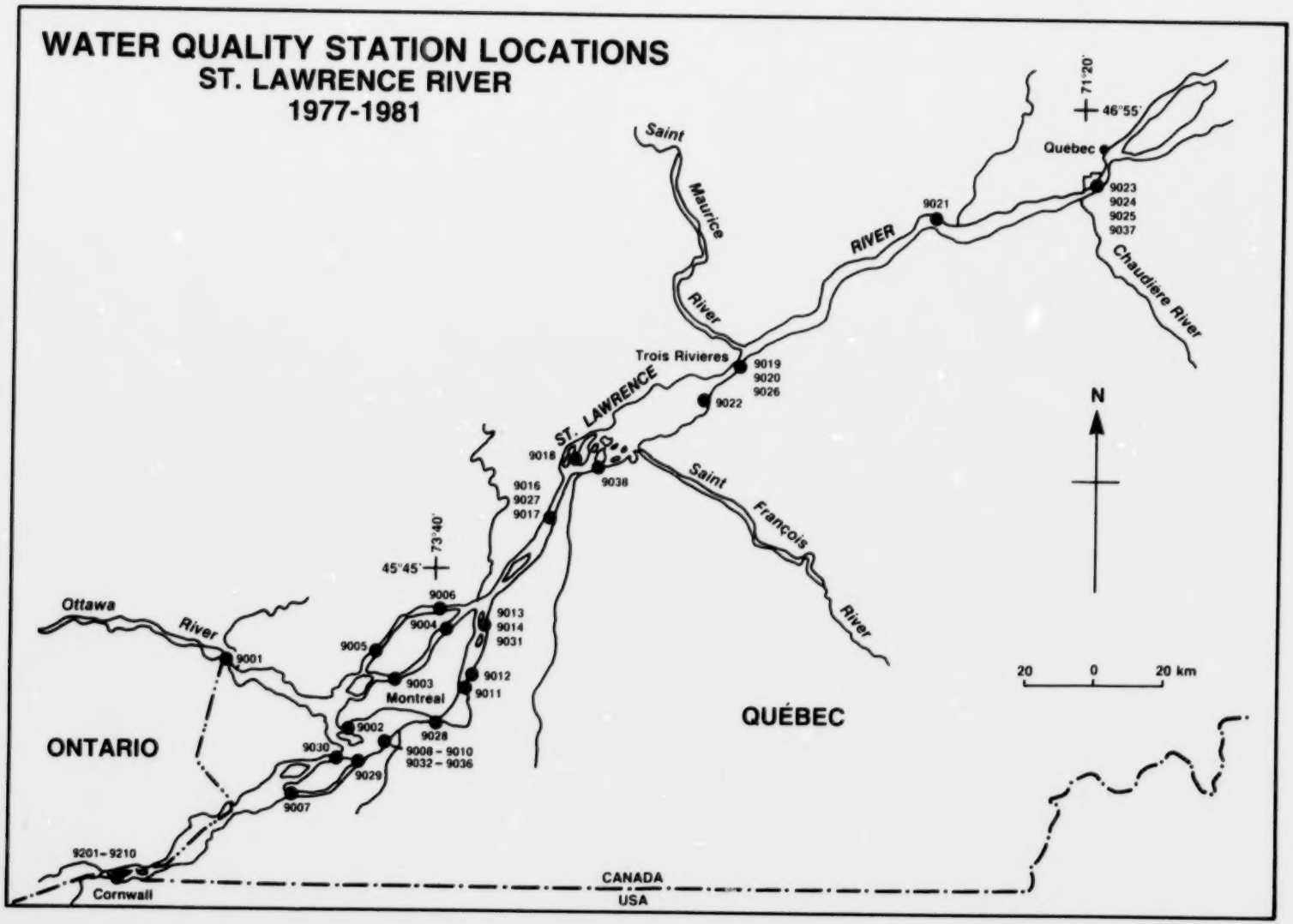

Figure 6. Water quality station locations, St. Lawrence River, 1977-1981.

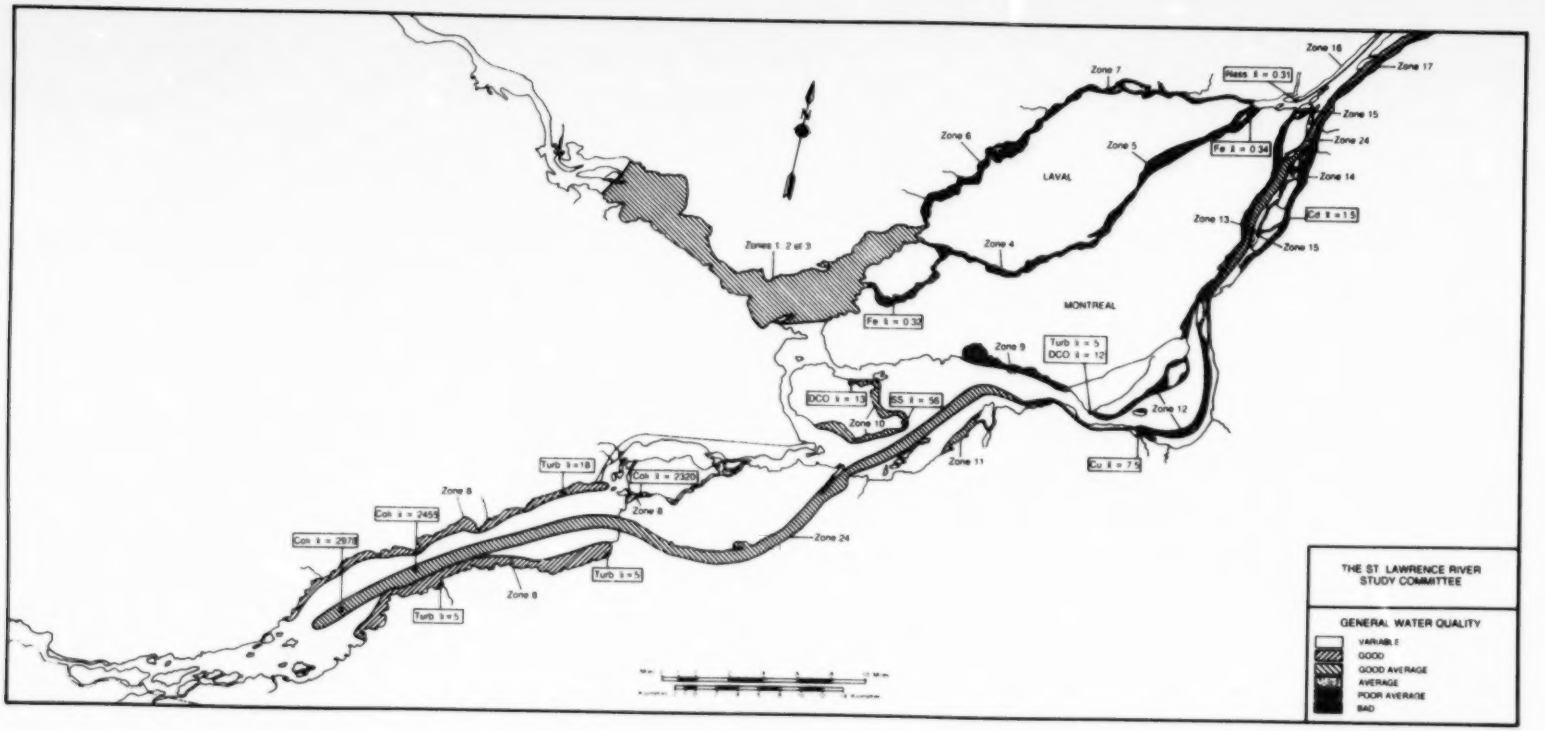

Figure 7. Natural channelization of the St. Lawrence River. Nass = Fixed nitrogen; DCO = Chemical oxygen demand.

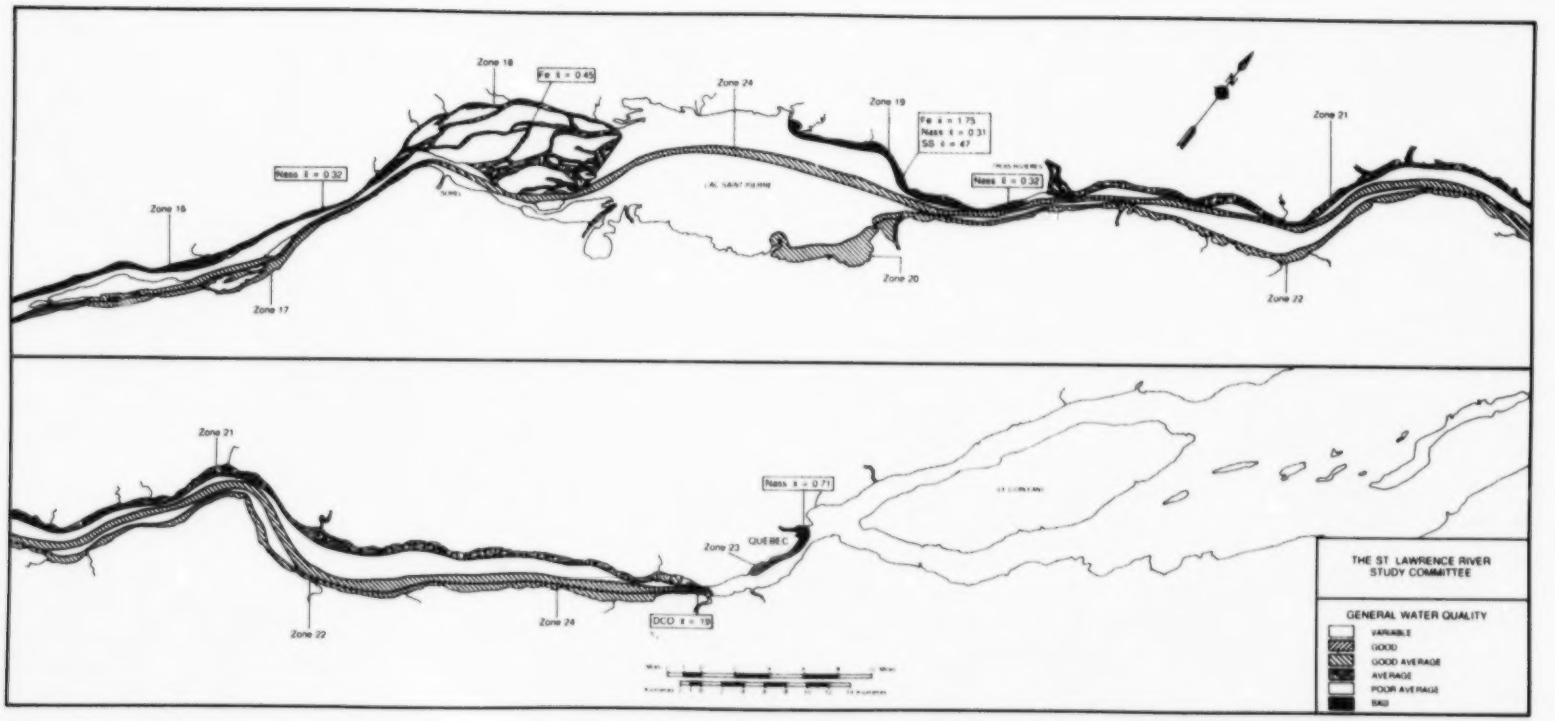

Figure 7. Continued.

section of the St. Lawrence. The five stations on Lac Saint-Louis (across from Beauharnois) were part of a special study to measure the suspended mercury in this lake. The remaining 32 stations were part of the general St. Lawrence water quality network (Fig. 6).

Not all users of the aquatic environment have strict water quality requirements. Disposal of industrial and municipal waste water requires only flowing water, whereas commercial navigation and hydroelectric power production have very few requirements. These, however, directly or indirectly create adverse conditions which limit other uses. As a result, the water quality in the St. Lawrence varies but is generally better in the high velocity navigation channel. Municipal and industrial effluents create particularly bad conditions along the shore at or below discharge outlets. These conditions continue far downstream because cross-stream mixing takes place slowly owing to the many islands in the Montreal to Sorel stretch of the river, resulting in a natural channelization of the St. Lawrence River between Montreal and Portneuf (Fig. 7). Thus, it is necessary to distinguish between the water quality near the shore and that in the channel. Three large mixing zones within the St. Lawrence River have been delineated through the analysis of specific conductance data (Fig. 8).

Vegetation occupies a large proportion of the shore in all sections of the St. Lawrence, particularly in Lac Saint-François, south of Lac

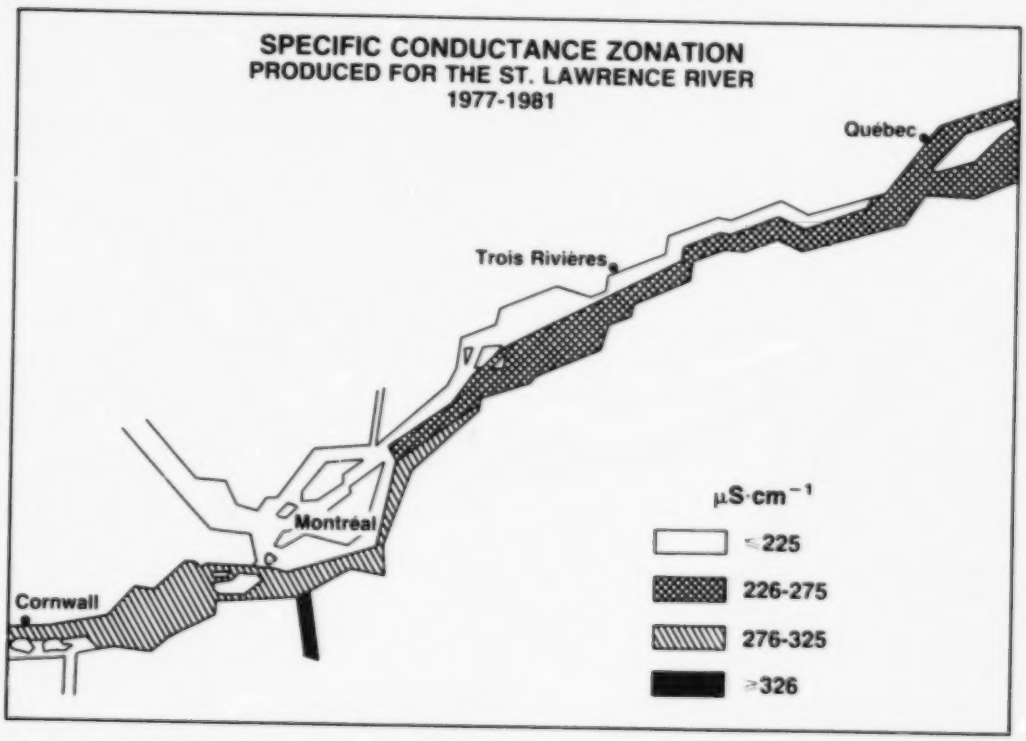

Figure 8. Specific conductance zonation produced for the St. Lawrence River, 1977-1981.

Saint-Louis, in the South Shore canal, in the des Prairies and Mille Iles rivers, Lac Saint-Pierre, south of the Gentilly sand bank and in the north arm of Ile d'Orléans. These natural areas are affected by changes in hydrodynamic conditions, the nature of the substratum, and nutrient enrichment. Accumulation of aquatic plant debris, or proliferation of filamentous algae on the edge of the banks, deteriorates the quality of the environment. During the second half of the season many vacationers complain that the banks require cleaning at their expense.

Sandy banks are not numerous in the area south of Montreal; the same holds true for the des Prairies and Mille Iles rivers and Lac Saint-Louis except for the upstream zones of the Mille Iles and des Prairies rivers, the area near Saint-Bernard Island and the de la Paix Islands. It should be noted that shoreline fill contributed by riparian interests and governments was not intended for beach development. Bathing conditions are favoured in the southeast section of Lac Saint-François, Lac des deux Montagnes, Oka, and Cap-Saint-Jacques. The river corridor and the north shore of the river estuary, from the mouth of the Saint-Maurice River to the mouth of the Sainte-Anne River, are also suitable for this purpose. Shoreline erosion is kept to a minimum by numerous retaining walls.

The aquatic environment produces, shelters and supports numerous living organisms and the quality of biological resources affects many uses, such as hunting and fishing. Fish and birds, however, are not the only important species in this region; there are, for example, micro-organisms which convert organic wastes, or again, aquatic plants which provide biological support by oxygenating the water and stabilizing the shores and riverbed.

When the quality of the "environment" is acceptable, the quality and diversity of the living world are maintained, which promotes full usage of the environment. At the opposite extreme, when the quality deteriorates, productivity increases to the detriment of diversity, and the mid- to long-term consequence is the degradation of the aquatic environment.

The quality of aquatic life can be indirectly quantified using indices based on productivity, diversity and inhibition (Table 1). Productivity applies to all trophic levels of the aquatic system, such as phytoplankton, zooplankton and fish. In an area as vast as that of the St. Lawrence, however, it is impossible to measure productivity efficiently at all trophic levels. The basic level, that of primary production, is sensitive to deterioration of the environment. Among others, two indices quantify this productivity: the fertility potential and the concentration of chlorophyll *a* in the water.

As Table 2 indicates, the quality of the water has repercussions on the quality of aquatic life as assessed by these indices. There are only two regions where there is no evidence of correlation between quality of aquatic life and quality of the water: the southern regions of the river corridor and the northern portion of Lac Saint-Louis. In all other regions the quality of life is good or poor in direct proportion to the quality of the water. The most deteriorated regions,

Table 1. Balance of Index Relative to Quality of Aquatic Life

Index	Absolute value of parameters	Quality of aquatic life
Productivity	Fertility potential	
	0 - 4	High
	4 - 10	Average
	>10	Low
	Chlorophyll *a* total	
	0 - 4.5 $mg \cdot m^{-3}$	High
	4.5 - 9.0 $mg \cdot m^{-3}$	Average
	>9.0 $mg \cdot m^{-3}$	Low
Diversity	<2 or more than 25% of sites	High
	<2 or more than 50% of sites	Average
	<2 or more than 75% of sites	Low
Growth	0 - 15	High
	15 - 50	Average
	>50	Low

Table 2. Relationship between the Quality of Aquatic Life and Water Quality

Regions	Quality of aquatic life	Water Quality
Lac Saint-François	High	Good
Lac des Deux Montagnes	High	Good
Lac Saint-Louis		
North	Average	Poor
South	High	Good
River corridor		
South - Montreal	Average	Poor
Montreal - Sorel	Average	Good
North - Montreal	Average	Poor
Montreal - Sorel	Low	Poor
Sorel delta (north)	Low	Average
Lac Saint-Pierre (north)	Low	Poor
Lac Saint-Pierre (south)	Low	Poor
River estuary	Average	Average
Quebec City region	Low	Poor

as indicated in Figure 9, are

(a) the northern region of the river corridor
(b) the Sorel delta
(c) the Quebec City region
(d) the whole of Lac Saint-Pierre.

It was concluded from the following study that the three main causes of deterioration in the quality of the St. Lawrence were deterioration of many of its tributaries, discharge of waste water, and landfill along shorelines. Their relative significance varies with the region. Urban flow and landfill headed the list of causes of deterioration of the des Prairies River; in the southern portion of Lac Saint-Pierre, tributary flow headed the list. It should be noted that regulation of flow and current, dredging and urban development had secondary effects on the quality of the environment.

The St. Lawrence was affected by six types of deterioration which, in order of decreasing significance, were

(1) dissemination of toxic substances
(2) bacteriological contamination
(3) encroachment on biological resource areas
(4) destruction of aesthetic value
(5) excessive suspended sediment
(6) nutrient enrichment.

The gravity of these deteriorations was heightened by hydrodynamic conditions peculiar to the St. Lawrence. Since most of the effluent was discharged close to the shore and because it took a long time to mix with the river water, the shoreline was particularly deteriorated. This made it necessary to constrain those uses dependent on quality, i.e., domestic water supply, swimming, conservation of biological resources, holidaying and residential development.

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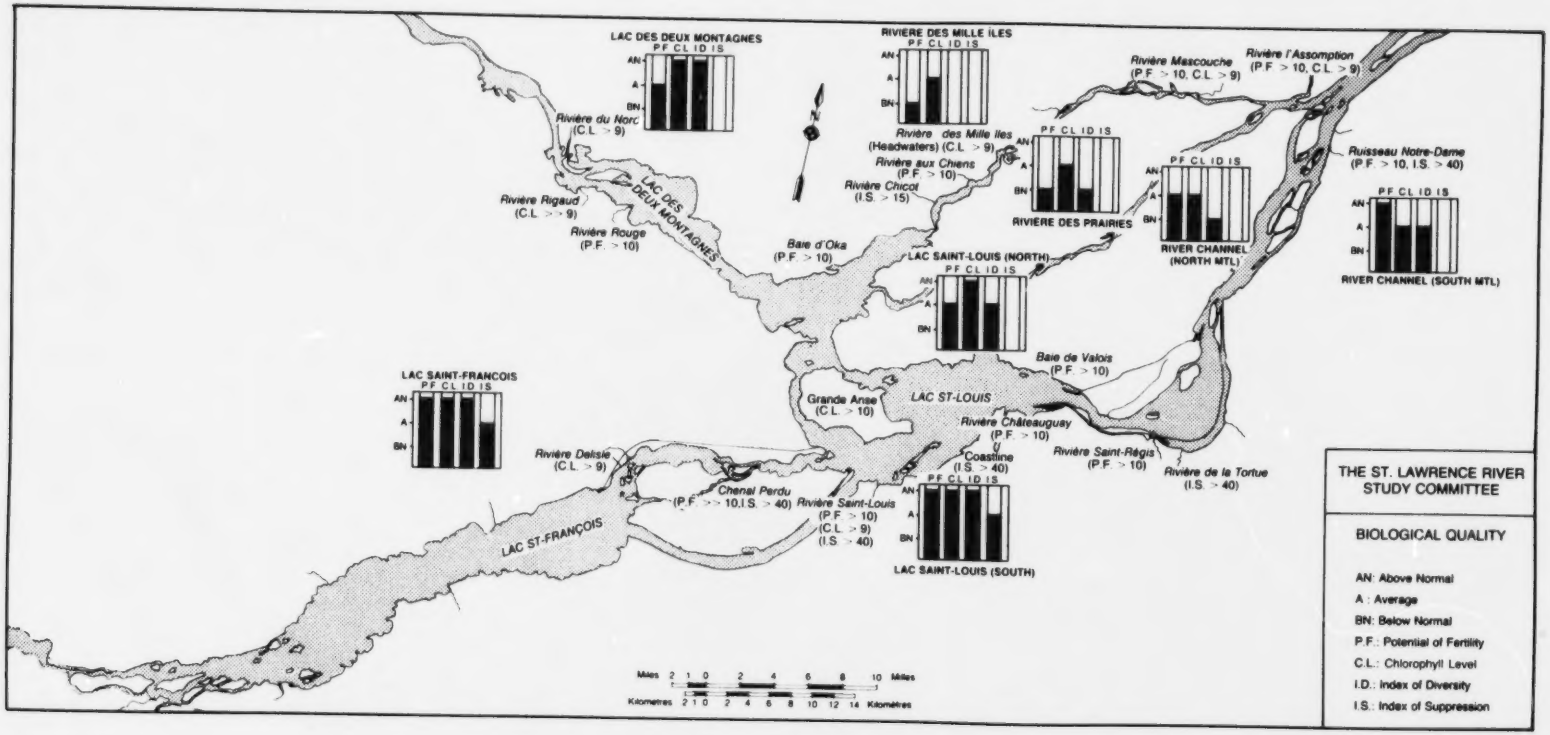
LAC DES DEUX MONTAGNES
P F C L I D I S
AN
A
BN
RIVIERE DES MILLE ILES
Rivière du Nord (C.L. > 9)
Rivière Rigaud (C.L. > 9)
Rivière Rouge (P.F. > 10)
LAC DES DEUX MONTAGNES
Rivière des Mille Iles (Headwaters) (C.L. > 9)
Rivière aux Chiens (P.F. > 10)
Rivière Chicot (I.S. > 15)
Rivière Mascouche (P.F. > 10, C.L. > 9)
Rivière l'Assomption (P.F. > 10, C.L. > 9)
Ruisseau Notre-Dame (P.F. > 10, I.S. > 40)
RIVIERE DES PRAIRIES
RIVER CHANNEL (NORTH MTL)
RIVER CHANNEL (SOUTH MTL)
Baie d'Oka (P.F. > 10)
LAC SAINT-LOUIS (NORTH)
Baie de Valois (P.F. > 10)
LAC SAINT-FRANCOIS
Grande Anse (C.L. > 10)
LAC ST-LOUIS
Rivière Châteauguay (P.F. > 10)
Rivière Delisle (C.L. > 9)
Coastline (I.S. > 40)
Rivière Saint-Régis (P.F. > 10)
Rivière de la Tortue (I.S. > 40)
Chenal Perdu (P.F. > > 10,I.S. > 40)
Rivière Saint-Louis (P.F. > 10) (C.L. > 9) (I.S. > 40)
LAC ST-FRANÇOIS
LAC SAINT-LOUIS (SOUTH)
Miles 2 1 0 2 4 6 8 10 Miles
Kilometres 2 1 0 2 4 6 8 10 12 14 Kilometres
THE ST. LAWRENCE RIVER STUDY COMMITTEE
BIOLOGICAL QUALITY
AN: Above Normal
A : Average
BN: Below Normal
P.F.: Potential of Fertility
C.L.: Chlorophyll Level
I.D.: Index of Diversity
I.S.: Index of Suppression

Figure 9. Water quality conditions in the St. Lawrence River, 1978.

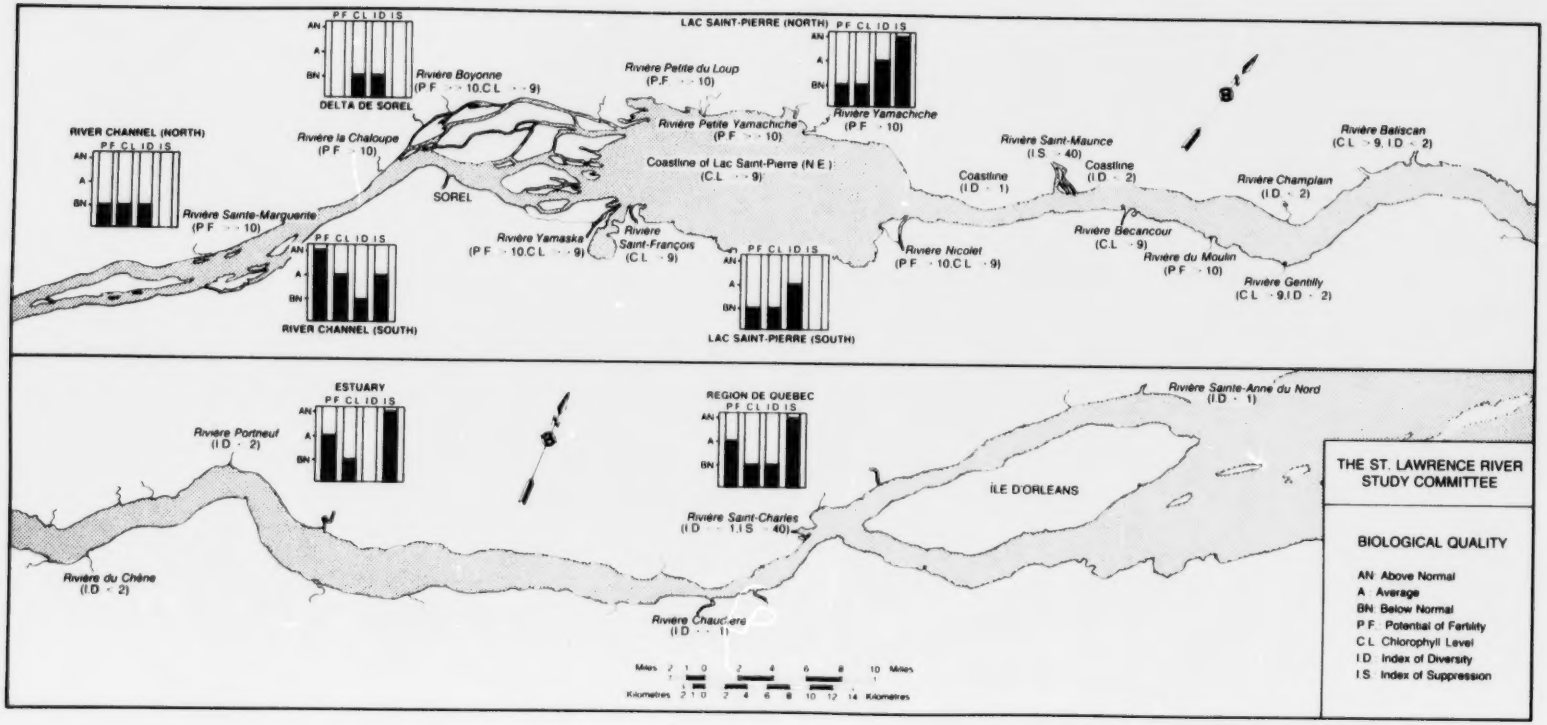

Figure 9. Continued.

NIAGARA RIVER

The Niagara River, with an average flow of 6400 $m^3 \cdot s^{-1}$, as measured at Queenston between 1975 and 1979, connects Lake Erie to Lake Ontario. Divided into upper and lower reaches by Niagara Falls, it provides 83% of the total tributary flow to Lake Ontario. For both Canada and the United States, it is a source of municipal and industrial water supplies, power generation, commerce, recreation and tourism (Fig. 1).

As a source of municipal drinking water, it serves a combined Canada/United States population of more than 400 000. The city of Buffalo municipal water plant, which obtains water at the junction of Lake Erie and the Niagara River, services an additional 530 000 people. The river, in return, receives the treated waste from these same populations.

The proximity to a source of cheap electrical power and water for use in industrial processing has made the Niagara area a highly industrialized area, particularly on the United States side. The Niagara River passes through a complex of steel, petrochemical and chemical manufacturing industries.

Early pollution concerns in the river included bacterial contamination, phenol problems, oil, excessive levels of iron, phosphorus, chloride and mercury, as well as general discoloration. Most of these contaminants have been reduced significantly over the last decade. Today, attention is focused on toxic substances in the Niagara River and in Lake Ontario and their effects on human health and the ecosystem. In addition to direct municipal and industrial discharges to the river, major toxic waste disposal sites have been identified along the river corridor. Their impacts on the safety of drinking water drawn from the river have become a public concern.

The presence in the river of toxic chemicals is not new. The development of more sophisticated equipment and methodology from 1974 to the present has led to greater detection capability, enabling chemicals to be found at very low concentrations. By 1978, public concern had arisen over the recurring detection of persistent, bioaccumulating toxic substances, particularly PCBs and mirex, in the biota and bottom sediments of Lake Ontario. Coincidentally, the gravity of the Love Canal situation was realized, and numerous other dumpsites were discovered along the U.S. side of the Niagara River. These included Hyde Park, 102nd Street and the S-Area dumpsites, all of which were reported to contain toxic chemicals. The environmental agencies of both Canada and the United States have undertaken exhaustive and detailed studies of the Niagara.

In partial fulfillment of Canada's commitment for surveillance and monitoring under the Canada-U.S. Great Lakes Water Quality Agreement of 1972 and its updating in 1978, the Water Quality Branch has conducted major water quality surveys on the Niagara River since 1975 (Table 3).

Table 3. Water Quality Branch, Ontario Region Activities on the Niagara River, 1975–1982

	Sampling at Niagara-on-the-Lake								Surveys throughout the river basin		
	Water						Suspended sediments				
Date	pH	Conductivity	Nutrients	Major ions	Metals	Organics	Metals	Organics	Water	Suspended sediments	Bottom sediments
1975	D	D	D	W	W	NS	NS	NS	X		
1976	D	D	D	W	W	NS	NS	NS			
1977	D	D	D	W	W	NS	NS	NS			
1978	D	D	D	W	W	NS	W or BW	W or BW			
1979	D	D	D	W	W	NS	W or BW	W or BW	X	X	
1980	D	D	D	W	W	W	W or BW	W or BW			
1981	D	D	D	W	W	W	W or BW	W or BW	X	X	X
1982	D	D	D	W	W	W	W or BW	W or BW			

D - Daily.
W - Weekly.
BW - Biweekly.
NS - No sample taken.
X - Samples taken.

The objectives of these studies were

(a) to determine trends in environmental water quality data
(b) to provide water quality information needed for management and protection of the environment
(c) to identify instances where environmental water quality objectives are being violated
(d) to identify new and developing problems in the environment.

In 1975, four surveys, each lasting three days, were conducted in May, July, September and December. During 1979, 11 single-day surveys were completed at approximately three-week intervals, between May and December. In 1975, five rows or ranges of four stations were sampled, and in 1979, six ranges of four stations were sampled. The range number indicates miles upstream from Lake Ontario (Fig. 10). In addition, a daily sampling program was established at Niagara-on-the-Lake. The strategic location of this station permitted the determination of representative quantities of material transported between Lakes Erie and Ontario. Initially, only daily nutrient and weekly major ion and trace metal samples were collected in response to the current environmental concerns. As attention was diverted from the problems of more conventional pollutants to those of toxic organic contaminants, this program was expanded to include weekly monitoring of suspended sediments as a possible source of toxic organics to Lake Ontario.

Statistically significant ($P \leq 0.05$) cross-stream and downstream variability was found in the Tonawanda Channel on 1979 yearly mean data for the following nutrient measurements: total phosphorus (Fig. 11), total filtered phosphorus, soluble reactive phosphorus, total Kjeldahl nitrogen, ammonia nitrogen, nitrate nitrogen, particulate organic carbon, particulate nitrogen and reactive silicate. Analyses of data from four surveys in 1975 and six surveys in 1979 indicated that values for extractable mercury, cadmium, chromium, lead, copper, manganese, zinc and nickel and total cadmium, copper, chromium, lead, arsenic and nickel were at or near the detection limits of the analytical methods. Few violations of the Great Lakes Water Quality Agreement (1978) specific objectives were found for these metals. The exception was total iron. Violations for total iron occurred 24% of the time in 1979, with half of them occurring in the last survey in December. Statistically higher concentrations of total iron were found in 1979, as compared with 1975 (Fig. 12). These high values were the result of natural climatic events such as heavy rainfall and high winds which increased shore erosion and resuspension of sediments to the river.

During both 1975 and 1979, total coliform, fecal coliform, fecal streptococci and aerobic heterotrophic bacterial analyses were completed on the upper Niagara River. No significant changes were observed between 1975 and 1979. The most obvious pattern in these data was the large difference in almost all parameters between the Chippawa (ranges 20.5 and 26.7), and the Tonawanda channels (ranges 19.5, 23.3 and 31.0). In addition, significant ($P \leq 0.05$) cross-stream differences were observed between stations in the Tonawanda Channel for fecal coliform, fecal streptococci and *Pseudomonas aeruginosa*. In the

Chippawa Channel, cross-stream total coliform and fecal streptococci counts were significantly ($P \leq 0.05$) different, while heterotrophs were significantly ($P \leq 0.05$) different in a downstream direction. Large increases, observed in both cross-stream and downstream direction in the Tonawanda Channel, are shown in Figure 13. These data are indicative of sources of bacteriological and organic pollution along the U.S. mainland side of the river. The relatively low levels of contamination in the Chippawa Channel indicate little or no contamination from Canadian sources. The 1972 Agreement objectives for bathing and swimming (i.e., contact recreational uses) for total coliform ($1000 \cdot 100\ mL^{-1}$) and fecal coliform ($200 \cdot 100\ mL^{-1}$) were often exceeded at ranges 19.5 and 23.3 in the Tonawanda Channel.

Figure 10. Sampling locations on the upper Niagara River, 1979.

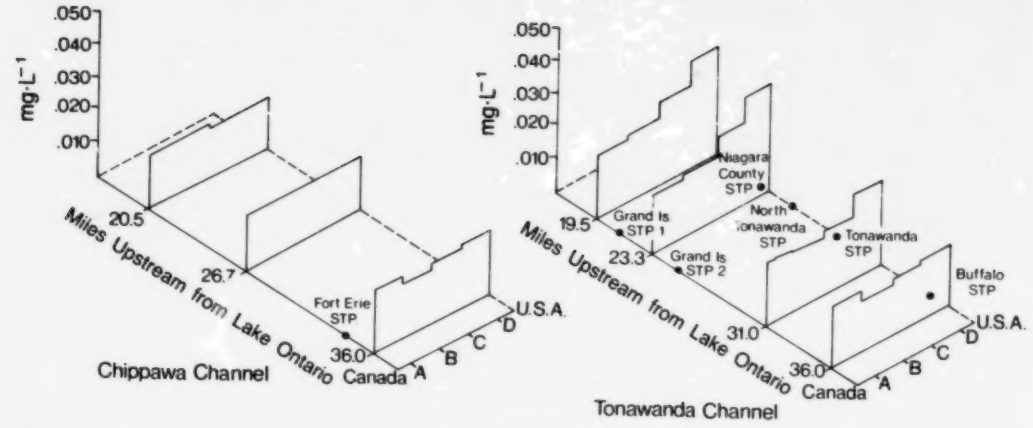

Figure 11. Upper Niagara River mean total phosphorus concentrations (mg·L⁻¹), 1979. STP = sewage treatment plant.

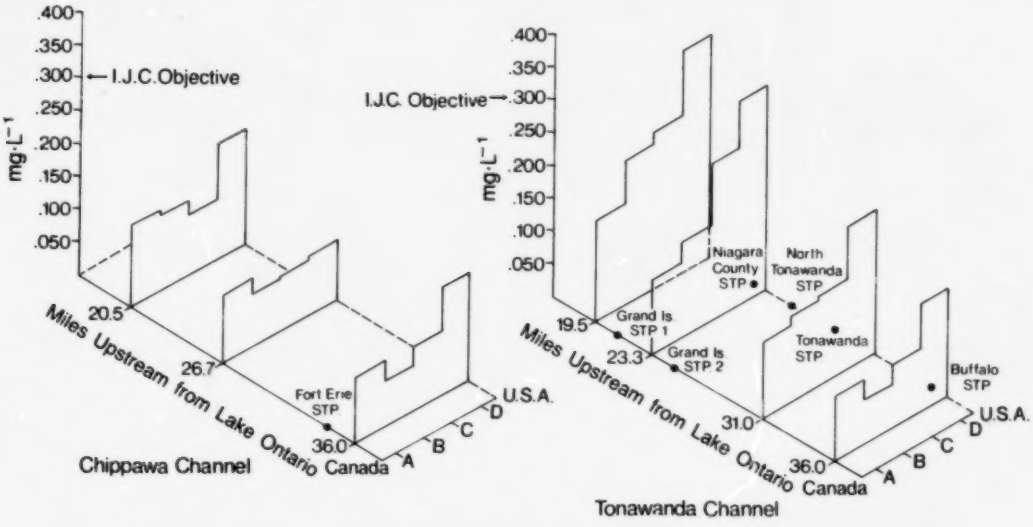

Figure 12. Upper Niagara River, mean total iron concentrations (mg·L⁻¹), 1979. STP = sewage treatment plant.

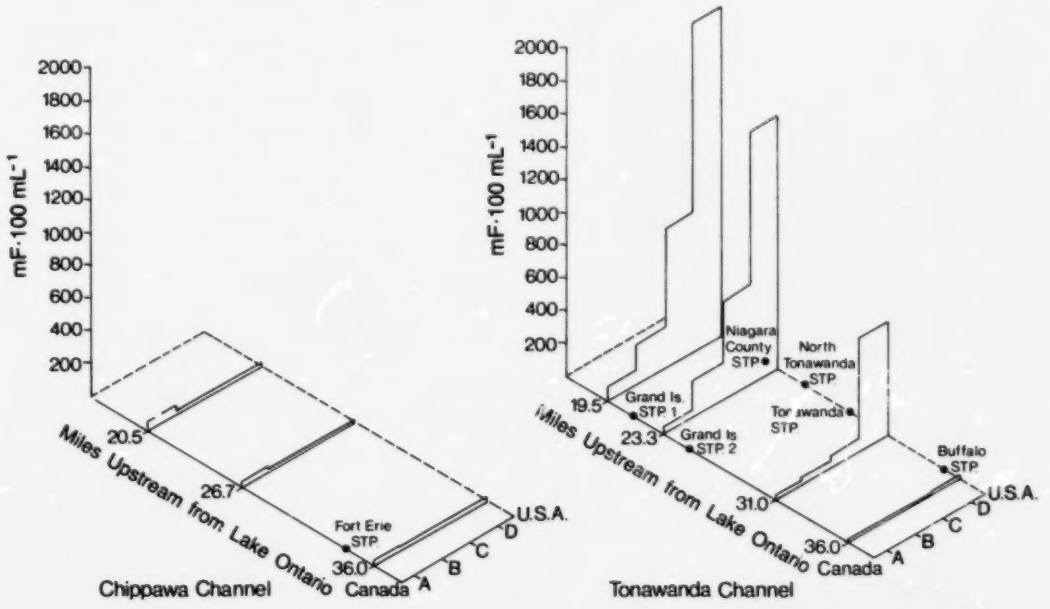

Figure 13. Upper Niagara River geometric mean total coliform concentration (CFU·100 mL⁻¹), 1979. STP = sewage treatment plant; mF = membrane filtration.

Concern had been expressed by environmentalists regarding the build-up of salt within the Great Lakes during the last 50 years. This increase had generally been blamed on the Detroit-Windsor complex, a major source of chloride loading to the Detroit River and thereby to Lake Erie, and to excess use of road salt for deicing purposes during the winter months. In 1971, the Detroit-Windsor complex significantly reduced chloride loadings to the lower Great Lakes. Analysis of the monthly average chloride concentrations at Niagara-on-the-Lake showed that a decrease in chloride concentration commenced in 1977, indicating that it took six to seven years for Lake Erie to respond to the reduced loadings (Fig. 14). This was two to three times longer than had been predicted.

During May 1981, a survey of trace metals in ambient water of both the upper and lower Niagara River was completed. Unfiltered water from 25 stations (Fig. 15) was sampled for total iron, cadmium, copper, lead, manganese, nickel, zinc, cobalt and chromium. Metal concentrations were generally higher in the surface waters of the Tonawanda Channel than in the Chippawa Channel, particularly for iron, zinc, copper and aluminum. Violations to the Great Lakes Water Quality Agreement occurred at the following stations: iron (8, Fig. 16), zinc (1), copper (14), and cadmium (1).

In addition to the measurement of violations of objectives, loadings of major ions, nutrients, trace metals and organic contaminants have also been calculated since 1976. Loadings to Lake Ontario from the Niagara River have shown a 20% decrease in chloride, a 22% decrease in total phosphorus, and a 60% increase in total iron between 1976 and 1982. Contaminant loadings, where they could be quantified, have shown a general decrease over a five-year period (1978 to 1982).

A new sampler, capable of extracting organics from a 200-L water sample, was used during the 1981 surveys to quantify contaminant concentrations throughout the river. It was determined that 24 trace metals and organic contaminants are being introduced to the Niagara River from point or non-point sources on the American shoreline of the river. The bottom sediment surveys confirmed these and better defined the magnitude of the problem (Fig. 17).

The upper Niagara River showed statistically significant cross-stream differences in total iron, total manganese and total zinc in the Tonawanda Channel. Levels of most metals were higher in the Tonawanda Channel than in the Chippawa Channel. Violations to the 1978 GLWQA specific objectives occurred frequently for total iron, especially during storm events in the eastern basin of Lake Erie. Other parameters, such as turbidity, fecal coliform and total phosphorus, also showed large increases during these events.

Concentrations of heptachlor epoxide, α-endosulfan, total PCBs, p,p'-DDE, α-BHC and all of the chlorobenzenes except dichlorobenzene in the aqueous fraction of the Niagara River increased by a factor of more than two from the Fort Erie inlet of the Niagara River to the Niagara-on-the-Lake outlet. This indicated that significant sources of these compounds are present within the basin itself.

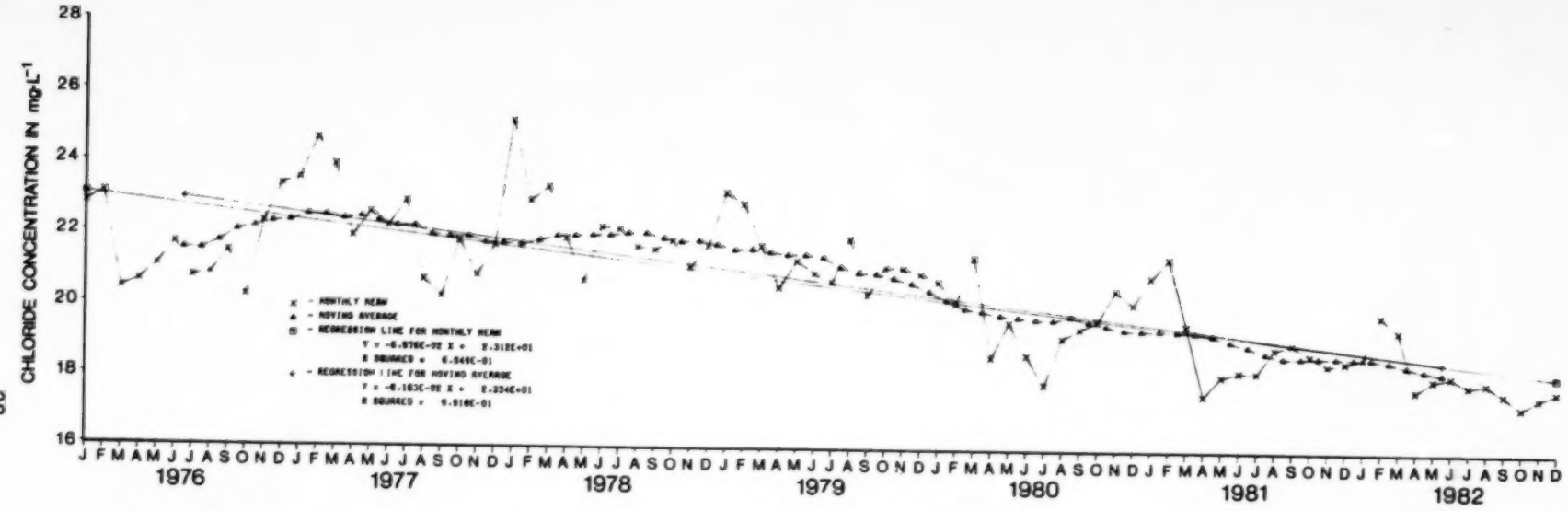
CHLORIDE CONCENTRATION IN mg·L⁻¹
28
26
24
22
20
18
16
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1976
1977
1978
1979
1980
1981
1982
x - MONTHLY MEAN
▲ - MOVING AVERAGE
□ - REGRESSION LINE FOR MONTHLY MEAN
Y = -6.979E-02 X + 2.312E+01
R SQUARED = 6.049E-01
◆ - REGRESSION LINE FOR MOVING AVERAGE
Y = -6.183E-02 X + 2.234E+01
R SQUARED = 9.918E-01

Figure 14. Monthly mean and 12-month moving average plot of chloride concentrations ($mg \cdot L^{-1}$) at Niagara-on-the-Lake.

Measurements of suspended sediments at five locations in the Niagara River in 1981 indicated that a higher concentration of suspended sediments occurred at Niagara-on-the-Lake than at Fort Erie. This nearly threefold concentration increase is probably the result of erosion, scouring of the river bottom and inputs.

Some compounds for which Lake Erie suspended sediments appear to be a significant source to the Niagara River are p,p'-DDE, α-BHC, p,p'-TDE, dieldrin, and α-chlordane. Recently calculated loadings from the Niagara River to Lake Ontario indicate that PCB loadings are about twice those previously reported, whereas DDT and mirex loadings have decreased.

As a result of these studies and others, a continuing effort is now being directed by both Canada and the United States to solve the complex problems of toxic substance contamination in the Niagara

Figure 15. Sampling locations on the Niagara River, May 1981, Trace Metal Survey.

River. The task is to assess what is there, identify the sources, implement additional appropriate abatement strategies, and monitor the effectiveness of these strategies. Future monitoring will closely follow the recommendations outlined by the Niagara River Toxics Committee in their 1984 report.

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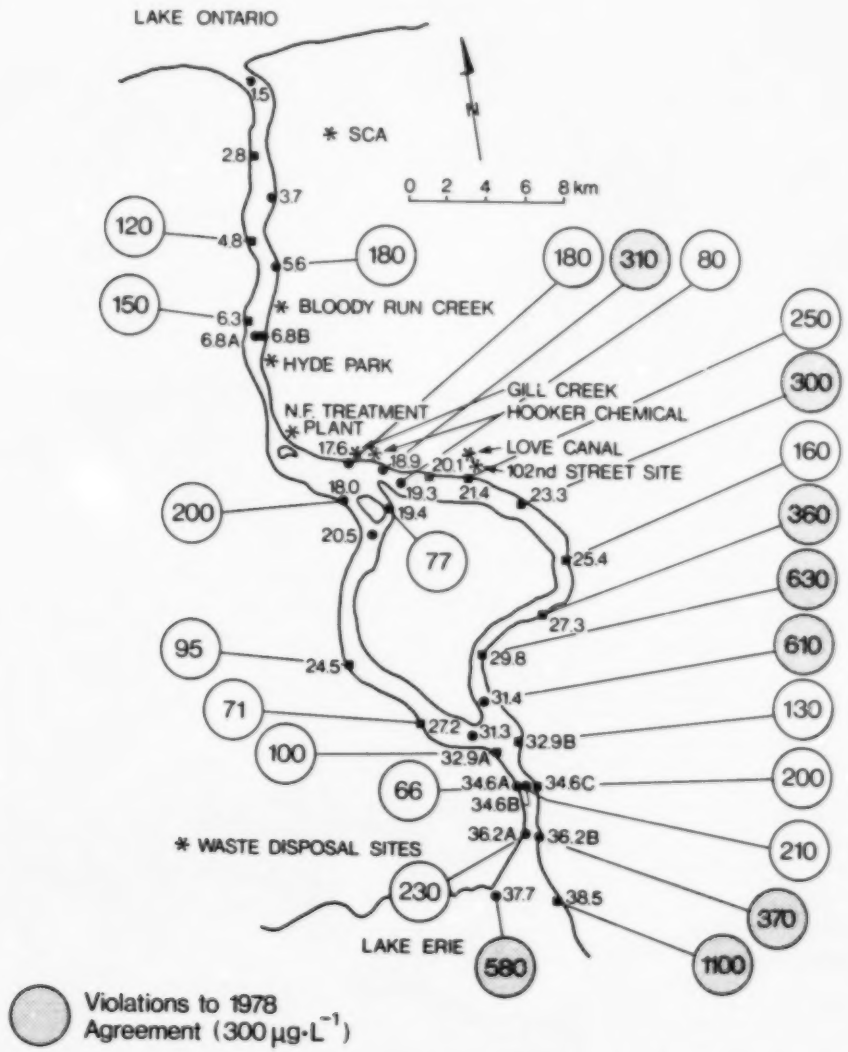

Figure 16. Total iron concentrations ($\mu g \cdot L^{-1}$) in water of Niagara River, May 1981.

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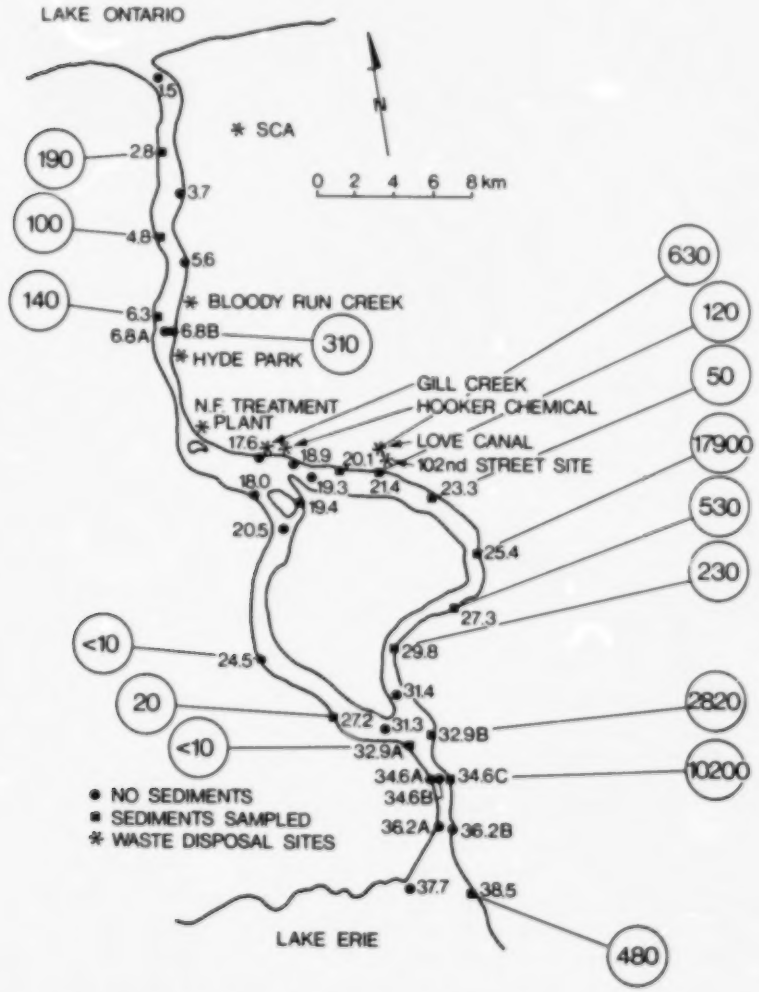

Figure 17. Distribution of total PCBs ($\mu g \cdot kg^{-1}$) in bottom sediments of the Niagara River, May 1981.

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SOURIS RIVER

The Souris River rises in Yellowgrass Marsh, located north of Weyburn in the southeast portion of the province of Saskatchewan. It flows in a southeasterly direction for 225 km to the International Boundary. The river continues southeasterly into the state of North Dakota to about 50 km southeast of Minot, where it turns north. It again crosses the border and enters the province of Manitoba where it follows a northeast course for about 160 km to its confluence with the Assiniboine River, near Wawanesa, Manitoba (Fig. 1).

The Souris River lies in the Hudson Bay drainage basin, in a region which is basically a flat to gently rolling plain with some hummocky regions. The plain is trenched by the valleys of the Souris River and its tributaries. The land surface within the study area varies in altitude from approximately 370 m above sea level at the Assiniboine River to about 830 m in the Moose Mountain Uplands, but for the most part lies in the 460- to 580-m range. The total length of the river approaches 1277 km. The drainage basin covers approximately 61 331 km^2, of which 29 733 km^2 lies in Saskatchewan; 22 015 km^2, in North Dakota; 130 km^2, in Montana; and 9453 km^2, in Manitoba.

Problems associated with flooding, inadequate water supplies and variations in water quality are prevalent in the Souris River basin in Canada. The threat of flooding and the water quantity and quality uncertainties act as retarding factors to economic development. The social and economic welfare of the people of the Souris River basin is dependent on the way in which its limited water and related resources are managed to serve such uses as agriculture, recreation, assimilation of wastes, and domestic, municipal and industrial water supply. Some of the problems and some development opportunities are affected by international water agreements and by existing and proposed projects and programs in the part of the basin in the United States.

Municipal and industrial effluent, intensive livestock operations and agricultural runoff have contributed increasingly to high levels of total dissolved solids. In addition, low levels of dissolved oxygen are experienced, especially under ice conditions. Algae problems have been encountered periodically by the town of Souris, which uses the river for its water supply.

In recognition of the water problems in the Souris River basin, the Canada-Saskatchewan Consultative Committee on Water and the Canada-Manitoba Advisory Committee on Water, two federal-provincial committees established under the Canada Water Act, set up a Souris River Basin Working Group in November 1970 and charged it with designing a study program for the formulation of a plan for managing the water and related resources of the Canadian portion of the basin. On October 28, 1974, the three governments signed the Canada-Manitoba-Saskatchewan Souris River Basin Study Agreement

(a) to carry out an assessment of the water and related resources of the Souris River basin
(b) to examine the demands being made and likely to be made upon the basin
(c) to set objectives relative to the management of the resources in Canada
(d) to develop an appropriate plan to meet these objectives.

The quality of the water in the Souris River and its major tributaries was assessed throughout the study area primarily during the open water months from April 1975 to October 1976. Most stations were monitored weekly and the information supplemented with other periodic measurements. The locations of the stations are shown in Figure 18. The water quality of the Souris River was found to be marginal for many uses. The climate and soils of the Souris River drainage area are the main reasons for this naturally poor water quality, rather than human activity. The soils are rich in bacteria, nutrients and salts such as sodium chloride, calcium carbonate and magnesium sulphate.

From the water quality survey performed it was found that nitrogen and phosphorus levels exceeded the water quality objectives set by Saskatchewan Environment in all seasons and at all locations (Fig. 19). The Souris River entering Manitoba from North Dakota contained about the same concentration of nitrogen as it did when it left Saskatchewan, but the mean concentration of phosphorus was approximately doubled from 0.16 to 0.27 $mg \cdot L^{-1}$ as P. The tributary streams in Manitoba diluted the level of concentration of phosphorus, but not to a point where it met the objective. In assessing the water quality in the Souris River at the point where it enters Manitoba, no attempt was made to ascertain the reasons for changes in water quality in the reach of the river between the Saskatchewan and Manitoba crossings. However, water quality data are being obtained by U.S. state and federal agencies at water quality monitoring stations in this reach which will facilitate a future examination of water quality problems, should the need arise.

Exceedances of the objectives for bacteria (greater than 2400 in 100 mL) and dissolved oxygen (less than 5.0 $mg \cdot L^{-1}$) were also observed but at only a few locations (Figs. 19 and 20). For example, one of 40 water samples taken from the Souris River below Weyburn's waste water outfall contained 450 000 coliforms in 100 mL, and another sample from the Souris River 16 km below Souris registered 23 000 coliforms in 100 mL.

Surface runoff appears to be responsible for most of the nitrogen and phosphorus that occurs in the waters of the basin. However, effluents from Weyburn and Souris produce local increases in the levels of these nutrients and bacteria and depressions in the levels of dissolved oxygen. Furthermore, the outflow from waterfowl refuges in North Dakota and the municipal effluent from communities in that state appear to increase concentrations of nitrogen, phosphorus and bacteria and to decrease levels of dissolved oxygen in the Souris River in Manitoba. For unknown reasons, in the reaches of the Souris River between Roughbark Creek and Estevan and between Melita and Napinka, increases in nutrients and bacteria and decreases in dissolved oxygen were noticed.

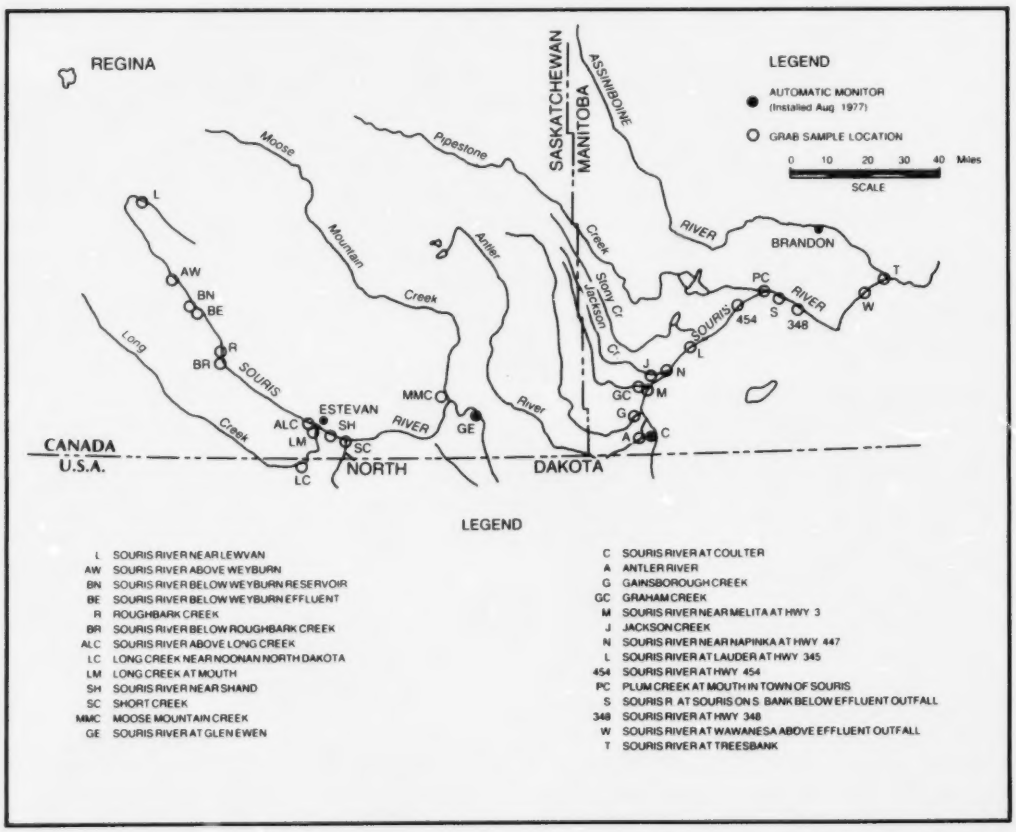

Figure 18. Water quality monitoring stations, Souris River, April 1975 to October 1976.

The biological data obtained were not definitive, but because of lower diversity indices and the presence of higher percentages of pollution tolerant organisms, indications are that there are water quality concerns (excessive nutrient concentrations, high biological oxygen demand (BOD) loadings, and low dissolved oxygen (DO) levels) below the effluent discharges of Weyburn, Melita and Souris. Except in Weyburn Reservoir, few locations were found to contain objectionable plant growth.

Metals and biocides were generally present at low levels. Higher than desirable concentrations of copper were found especially in the Weyburn Reservoir. Zinc levels in the Boundary Reservoir were occasionally found to exceed the objectives. Iron and manganese were the only two metals detected in significant concentrations in the Souris River Basin (Fig. 20).

The waters of the Souris River are naturally rich in nitrogen and phosphorus. Increased surveillance of intensive livestock operations is needed to determine whether any such operations are contributing to the trophic problems within the basin; if problems are identified, then a program should be developed to cope with the situation. Municipal effluent discharge to the Souris River from the towns of Weyburn, Saskatchewan and Souris, Manitoba, produces local increases in the levels of total dissolved solids, nutrient and bacterial pollution as well as decreased levels of dissolved oxygen. The upgrading of sewage treatment for both towns is needed. The quality of water in the Souris River in Manitoba is affected, to a considerable degree, by activities in North Dakota. Indications are that most of the pollution is caused by the wildlife refuges situated along the Souris River between Lake Darling and Westhope. Pollution is also caused by effluents from municipal sewage treatment facilities and by return flows from irrigation projects. Expansion of any of these activities would cause further water quality deterioration in the Souris River in Manitoba.

Two large water management projects planned for North Dakota, the Garrison Diversion Unit (GDU) and the Burlington Project, could have a significant effect on water and water-related resources in the Souris River basin in Canada.

The Garrison Diversion Unit was designed to divert water, principally for irrigation purposes, from the Missouri River into the Souris and Red River basins in North Dakota, and the Burlington project will consist of the construction of a dam and a flood control reservoir on the Souris River near Burlington, North Dakota. Serious concerns about the quality and quantity of water entering Canada, and the introduction of foreign biota to these waters, have been raised as a result of the project.

The primary concerns with water quality relate to the state of return flows from areas irrigated by the GDU. These waters are expected to have increased levels of total dissolved solids, nitrates, sulphates, sodium and heavy metals. Municipal sewage as well as fish and wildlife developments along the U.S. portion of the river are expected to contribute further nutrient pollution and contaminants to the flow.

It is anticipated that changes in water quality and quantity will affect the fish and wildlife populations in Manitoba. Introduction of foreign fish species, fish diseases and parasites is also expected to disrupt commercial and sport fishing in the Province.

Wildlife refuge impoundments in the Des Lacs River, Lake Darling Reservoir and Westhope area (i.e., Des Lacs National Wildlife Refuge,

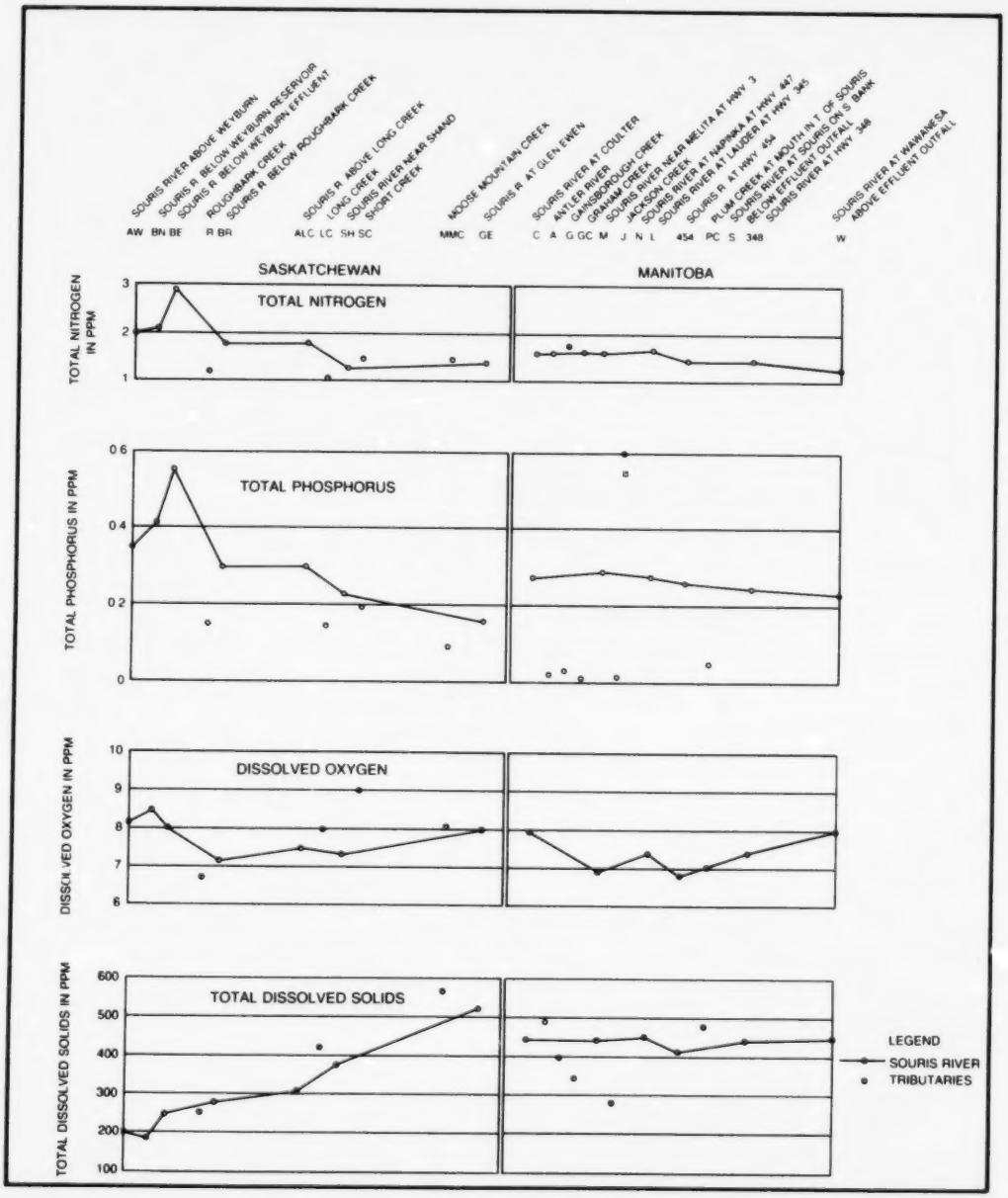
SOURIS RIVER ABOVE MEYBURN
SOURIS R. BELOW MEYBURN RESERVOIR
SOURIS R. BELOW MEYBURN EFFLUENT
ROUGHBARK CREEK
SOURIS R. BELOW ROUGHBARK CREEK
SOURIS R. ABOVE LONG CREEK
LONG CREEK
SOURIS RIVER NEAR SHAND
SHORT CREEK
MOOSE MOUNTAIN CREEK
SOURIS R. AT GLEN EWEN
SOURIS RIVER AT COULTER
ANTLER RIVER
GANSBOROUGH CREEK
GRAHAM CREEK
SOURIS RIVER NEAR MELITA AT HWY 3
JACKSON CREEK
SOURIS RIVER AT NAPINKA AT HWY 447
SOURIS RIVER AT LAUDER AT HWY 345
SOURIS R. AT HWY 454
PLUM CREEK AT MOUTH IN T. OF SOURIS
SOURIS RIVER AT SOURIS ON S. BANK
BELOW EFFLUENT OUTFALL
SOURIS RIVER AT HWY 348
SOURIS RIVER AT WAWANESA
ABOVE EFFLUENT OUTFALL
AW BN BE R BR ALC LC SH SC MMC GE C A G GC M J N L 454 PC S 348 W
SASKATCHEWAN
MANITOBA
TOTAL NITROGEN
TOTAL NITROGEN IN PPM
TOTAL PHOSPHORUS
TOTAL PHOSPHORUS IN PPM
DISSOLVED OXYGEN
DISSOLVED OXYGEN IN PPM
TOTAL DISSOLVED SOLIDS
TOTAL DISSOLVED SOLIDS IN PPM
LEGEND
SOURIS RIVER
TRIBUTARIES

Figure 19. Measurements of nitrogen, phosphorus, dissolved oxygen and total dissolved solids, Souris River, April 1975 to October 1976.

Upper Souris National Wildlife Refuge and J. Clark Salyer National Wildlife Refuge) have been in operation to control the flows and availability of water within North Dakota. Outflows from the refuges increase nutrient and bacterial pollution as well as decrease dissolved oxygen in the Manitoba portion of the Souris River. Pollution of this nature is expected to increase.

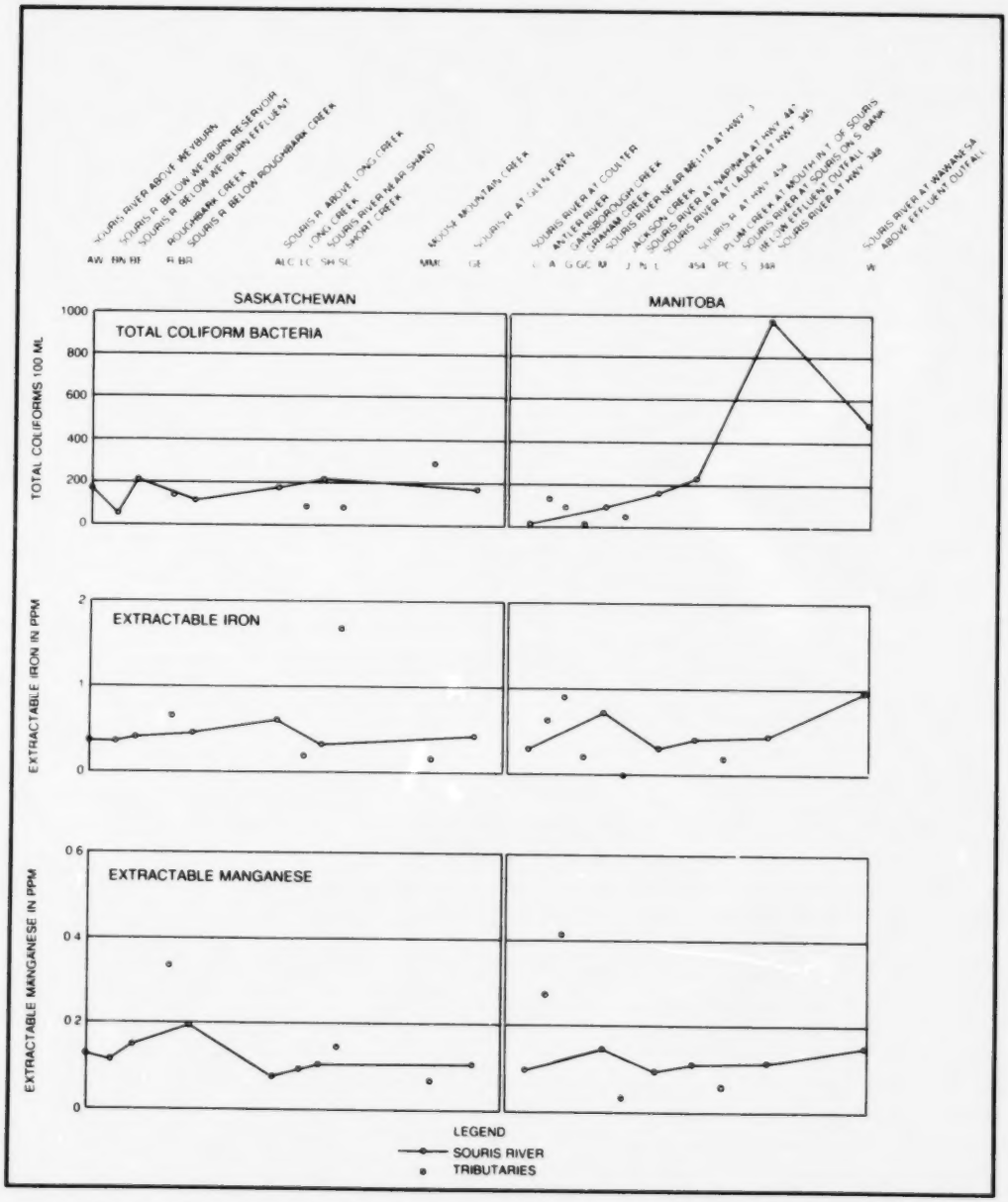

Figure 20. Measurements of coliform bacteria and metals, Souris River, April 1975 to October 1976.

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FRASER RIVER ESTUARY

The Fraser River drains an area of 230 000 km and flows about 1400 km from its headwaters in the Rocky Mountains to the Strait of Georgia (Fig. 1). It supports a large commercial salmon fishery and is also important for sportfishing. The river is a migration route for juvenile and adult salmon and a rearing area for various salmon and trout. The estuary is one of the world's most productive fish, wildlife and agricultural areas. The wetlands support an annual catch of eight million adult salmon and over one million migratory birds on the Pacific Flyway. Farmland in the Fraser floodplain provides much of Canada's fresh vegetable and berry crops. These assets are highly valued for their economic value and recreational potentials and will form a critical component in Canada's food strategy in coming years.

The Fraser River receives municipal effluent and storm water originating from the largest population centre in the Province and points upstream. It also receives a multiplicity of industrial discharges. It is used by commercial shipping and recreational boating, and for transporting log booms which are stored along much of its shoreline. The water is not used as public water supply, although it offers some opportunities for swimming. Water in ditches and backwaters is used for agricultural irrigation in the summer.

In 1977, under an agreement between Environment Canada and the British Columbia Ministry of Environment, the Fraser River Estuary Study was initiated. Its purpose was to develop a management program that would guide future changes in the estuary so that it would be preserved and protected as a natural resource while continuing to serve as a vital economic resource. The study was a multi-agency program of activity involving federal, provincial, municipal and regional agencies, industry and public interests.

The main objectives of the study were

(a) to summarize all the data collected between 1970 and 1978 that describe discharges, water quality and aquatic biota in the study area
(b) to analyze these data in an attempt to understand how discharges and natural processes affect water quality and aquatic life
(c) to recommend action that may be needed to prevent degradation of water quality over the next 20 years. The recommendations would be based on an analysis of control measures that could be used in the study area
(d) to recommend programs to fill important data gaps
(e) to recommend a monitoring program for the river and the main discharges.

The study focussed on the land and water outside the boundary of the dykes between Kanaka Creek and the outlet of Pitt Lake in the east, the estuary drop-off in the west, Point Grey to the north, and the International Boundary to the south. The study area also included Boundary and Semiahmoo bays (Fig. 21).

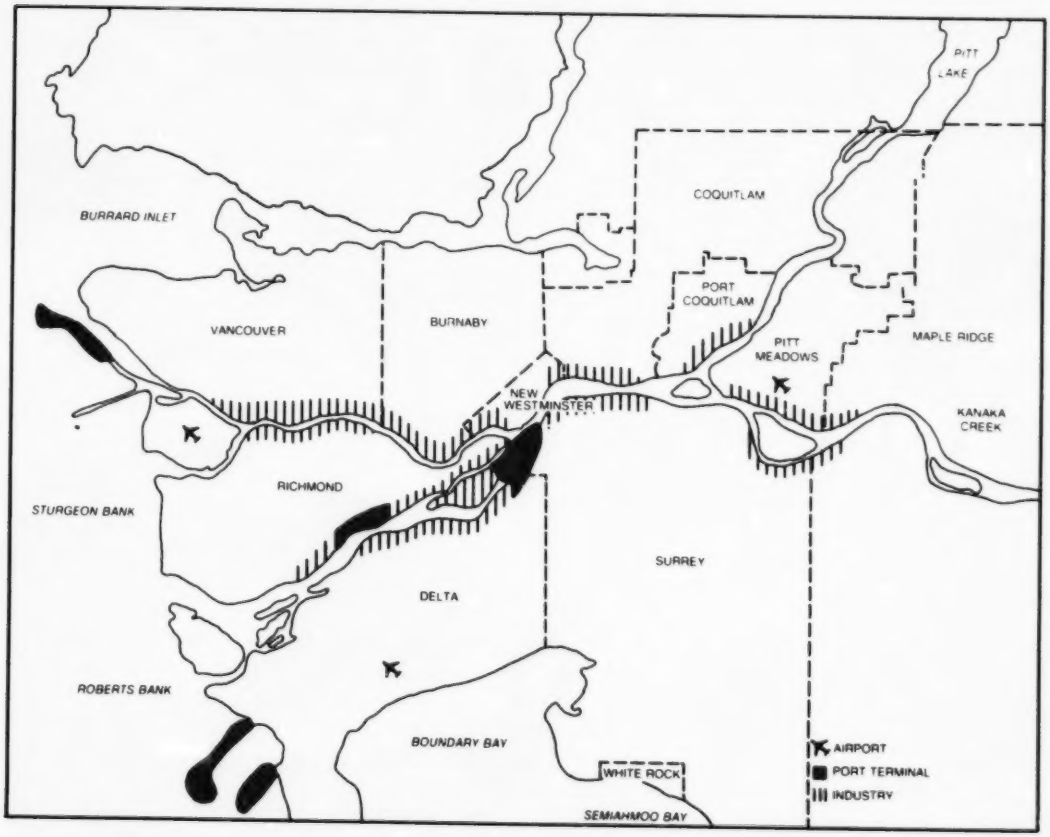

Figure 21. Fraser River Estuary.

The river entering the study area is called the Main Stem. The river then divides into two branches at New Westminster: the North Arm which contains 15% of the flow and the Main Arm (also referred to as the South Arm) which carries 85% of the flow. Near the mouth, the North Arm further divides into two approximately equal branches, the south branch being called the Middle Arm. The Main Arm also subdivides into two branches, the smaller called Canoe Pass and carrying 5% of the flow.

Water movement is complex because it is affected by tides in much of the study area. The tidal cycle changes river speeds and water levels and reverses the direction of flow for varying times and distances. At high tide and low river flow, a salt wedge can move up the Main Arm, to as far as the Main Stem. The salt wedge also penetrates the North Arm, but does not reach the Main Stem as a discrete form from this direction.

Most water quality variables in the river are not measurably changed by the major discharges. However, measurable changes may occur in dilution zones, and there is concern over the additive effect of these zones. The large flow provides a buffer against the effects of many pollutants and ensures that oxygen levels remain high in main channels. However, low dissolved oxygen conditions can periodically occur in sloughs and backwater areas. Pollutant concentrations have generally remained below levels considered immediately toxic to fish. Fecal coliform levels are high enough to close bathing beaches in the river but are within provincial standards in the outer estuary. Molluscan shellfish harvesting is not allowed in the Fraser River Estuary owing to the elevated fecal coliform counts. Input into the lower Fraser River, such as agricultural runoff, landfill leachates, sewage treatment effluents, industrial waste water (Fig. 22) and storm sewer discharges (Fig. 23), contain harmful microorganisms. During periods of heavy rainfall, combined storm and sanitary sewers may discharge material which has bypassed or been diverted upstream from sewage treatment plants. The receiving waters of the lower Fraser River transport these discharges to the sea (Fig. 24), where various factors, including dilution by, and bactericidal properties of, seawater, ultimately reduce numbers of bacterial indicators of fecal pollution (coliforms) to below detectable limits.

Steps have been taken to improve water quality over the years. These include primary treatment of municipal sewage, requirement of permits for major discharges to the river, and improved enforcement of pollution standards.

Analyses of data from several North Arm reaches have shown that the annual geometric means of coliform values changed from above $2000 \cdot 100\ mL^{-1}$ in 1970 to 1975, to below $1000 \cdot 100\ mL^{-1}$ in 1976 to 1977. This change was attributed to the diversion of sewage effluents from the North Arm to the Annacis Island sewage treatment plant. Despite this progress, significant tasks remain. These include control of toxic wastes, upgrading of sewage treatment plants and landfills, and improved enforcement of pollution control legislation.

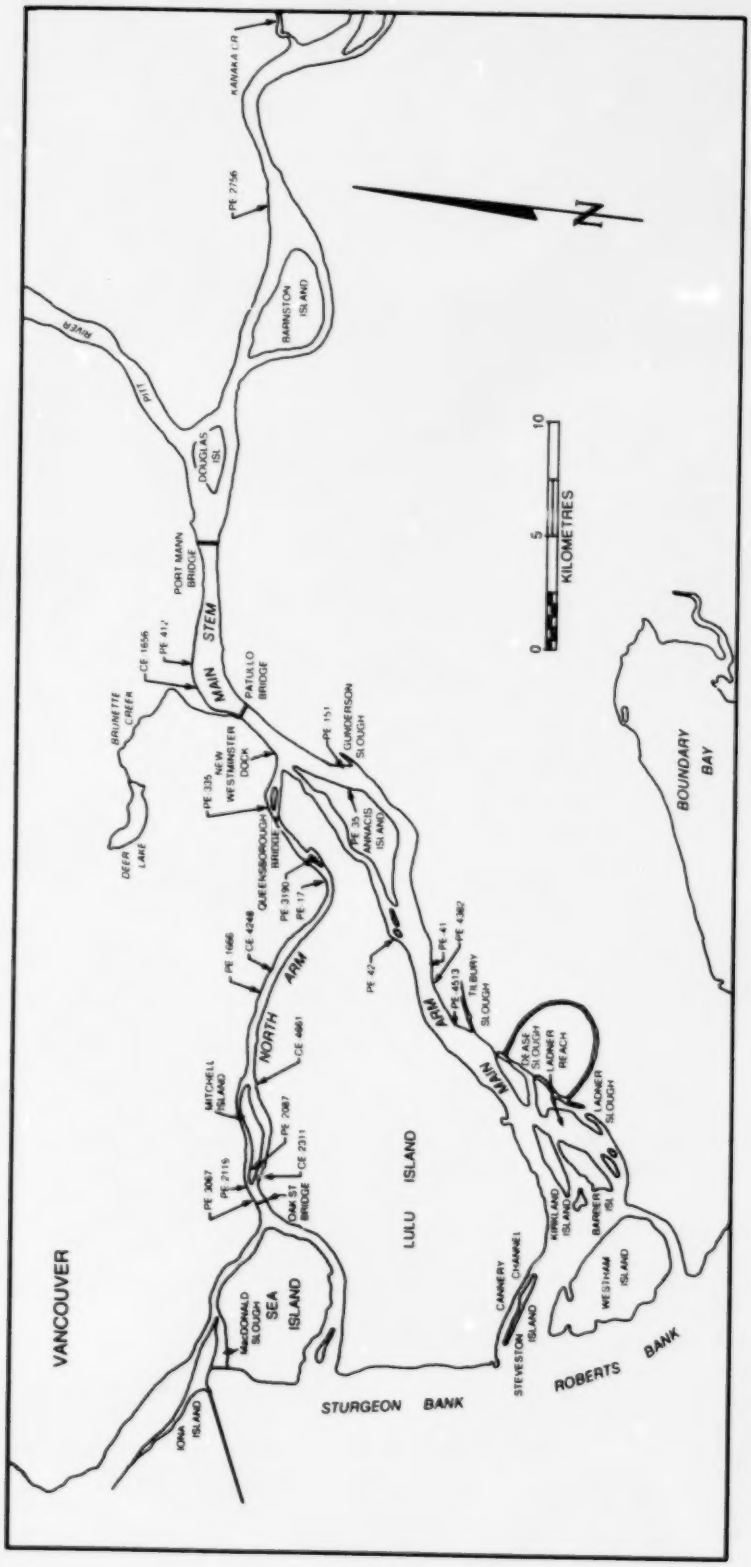

Figure 22. Location of the main industries discharging to the Fraser River between 1970 and 1978.

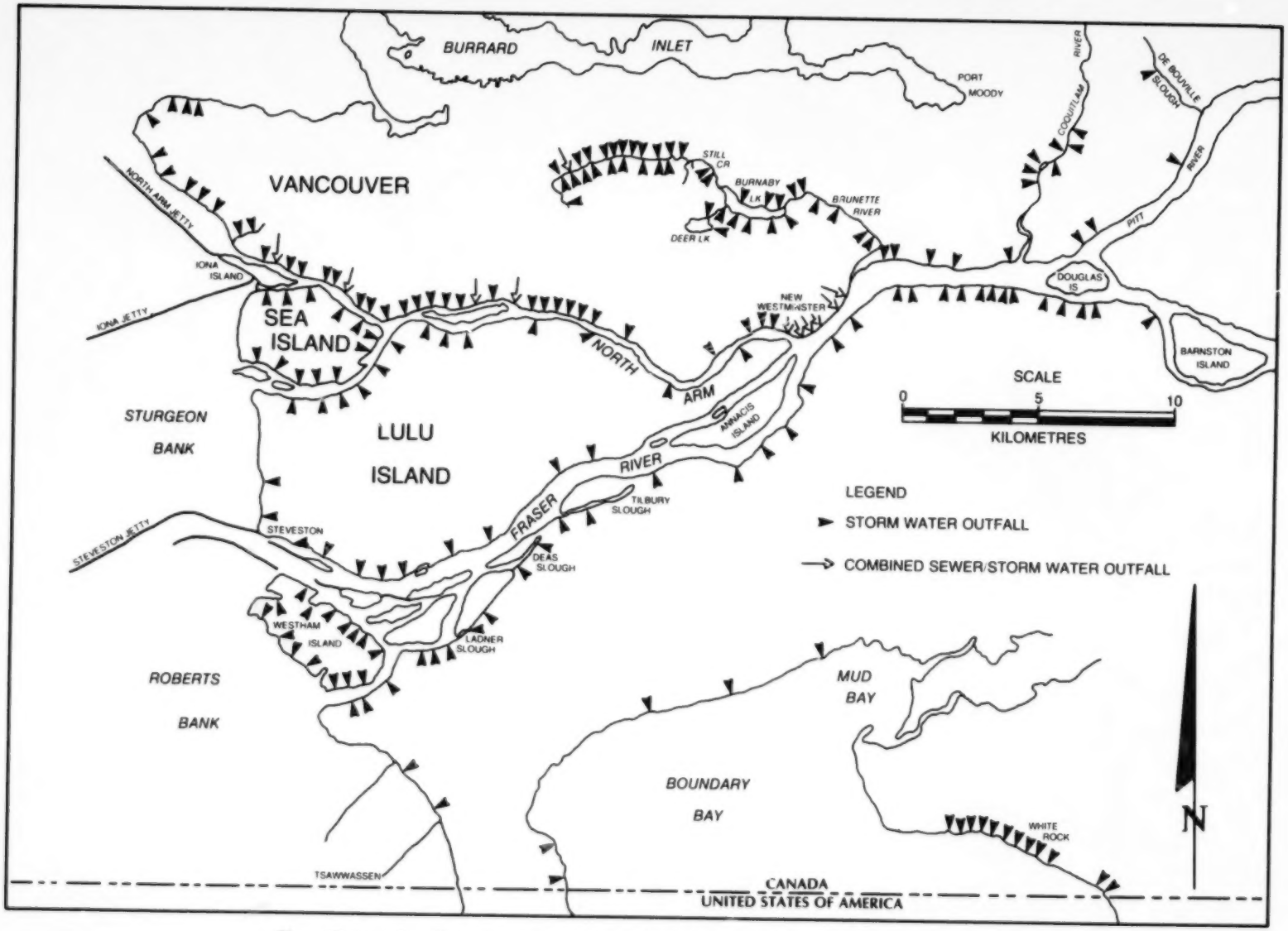

Figure 23. Location of storm sewer outfalls discharging to the Fraser River between 1970 and 1978.

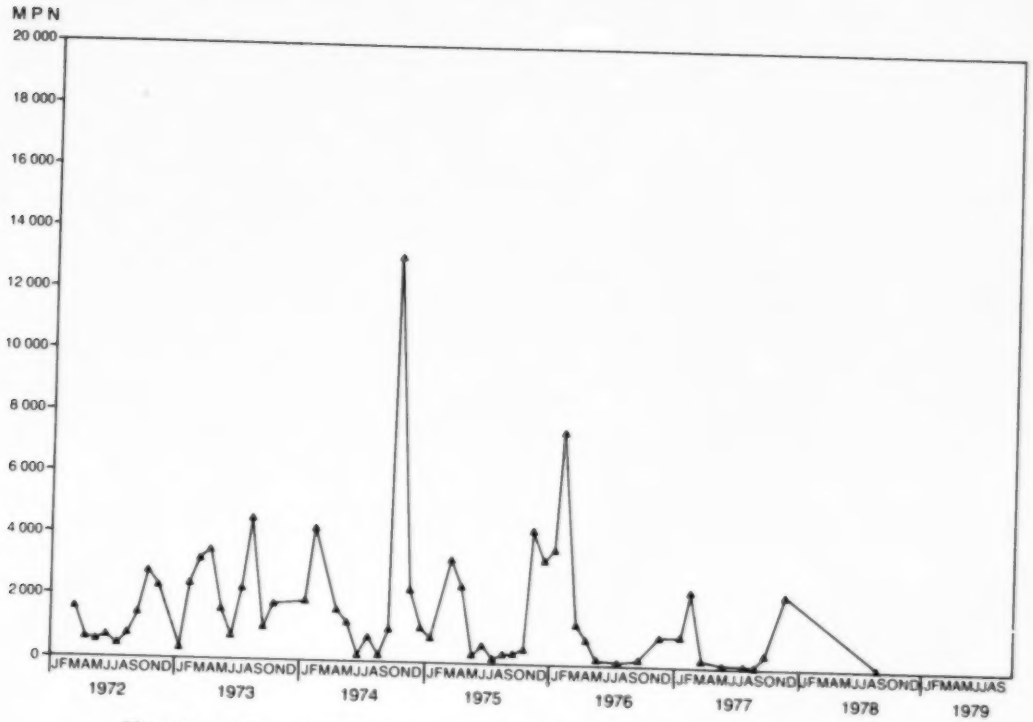

Figure 24. Tilbury Island, monthly means for fecal coliforms. MPN = most probable number.

There are over 100 industrial outfalls to the river. In addition, industry discharges to municipal sewer systems. Monitoring programs have shown that discharge from the Iona Treatment Plant has degraded parts of Sturgeon Bank (Fig. 25). The feasibility of a deep sea outfall is currently being examined as a potential solution to this problem.

Although large areas of foreshore habitat and agricultural land have been lost, recent steps by all levels of government have enhanced the possibility of retaining remaining assets. Critical habitats have been purchased. The salmonid enhancement program is aimed at restoring historic salmon stocks. Recent amendments to the Fisheries Act give increased protection to fish and fish habitat. Provincial legislation and regional plans protect productive farmland.

It is anticipated that work on the Fraser River will intensify in the future, concurrent with the Federal-Provincial Agreement for Water Quality Monitoring and implementation of the Fraser River Estuary Management program. The federal government will cooperate with other government agencies in monitoring, surveys and the development of water quality objectives.

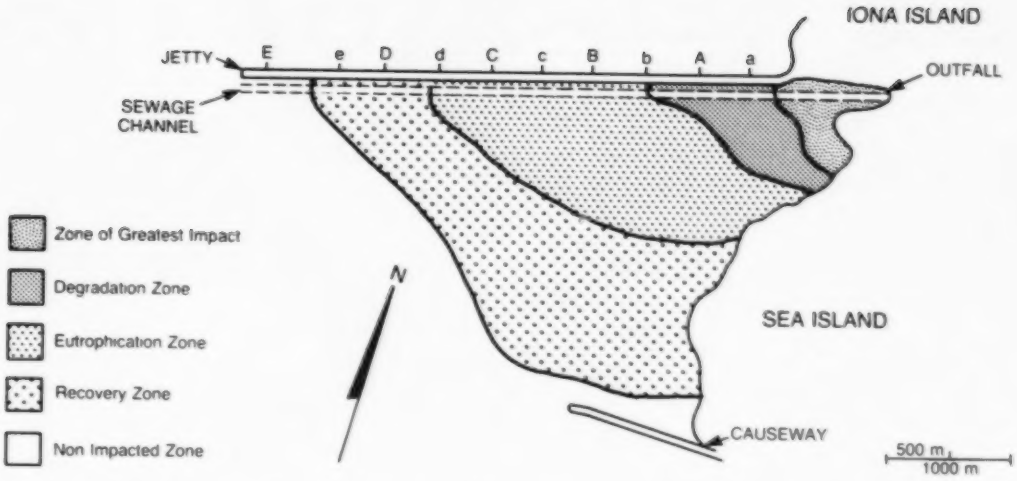

Figure 25. Zones of impact resulting from the Iona STP discharge. STP = sewage treatment plant.

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CONCLUSIONS

Water quality variables within a river system, from the headwaters to its mouth, present a continuous gradient of environmental conditions. Superimposed on this spatial gradient is the effect of the seasonal cycle and long-term changes. Thus, not only are there changes in a river basin downstream (spatially) but also at a given point (temporally). Water quality monitoring, through the interpretation of collected data, identifies the significant issues, existing and

potential, within a given river basin. River basin monitoring identifies the source of pollution, establishes cause-effect relationships and provides the basis for planning alternatives in terms of their impacts upon the aquatic ecosystem. Since no two river basins are identical, nor are the issues associated with them, monitoring programs are specifically established to provide the necessary information to protect and enhance the individual river basin.

Historically, most of this federal water quality evaluation has been located on the U.S. border or on borders between the different Canadian provinces. Provincial governments, responsible for resources within their boundaries, carry out their own water quality studies. Federal-provincial agreements are now being signed to ensure that water quality activities, such as network design, data collection, analysis, storage and interpretation, are carried out in the same way by federal and provincial agencies.

In 1985, there has been an effort to improve the national water quality information base through the development of two complementary networks - one a national index network and the other, a specialized recurrent basin network. In Canada, there is a move away from the idea of solely having a series of fixed stations, with fixed sampling at specific times for water quality. This is evolving to an understanding of what happens in basins, that is, considering basins as a unit.

The national network will be a series of index stations across Canada to determine changes and long-term trends of water quality. Combined with the index stations will be an array of river basin stations to be monitored on a recurring basis, thereby developing an understanding of water quality issues in a dynamic comprehensive manner.

The goals of the national network are

(a) to determine changes in long-term trends
(b) to detect emerging problems as they appear at provincial and international boundaries to determine the effectiveness of regulatory action
(c) to establish and determine compliance with water quality objectives
(d) to determine the requirements for special studies and research.

In addition to knowing the status of ambient water quality in relation to the criteria established for the protection of designated uses, there is a need to know the causes of water quality degradation and what remedial actions will improve the situation. Thus the sampling programs to be conducted in the basin studies are to be problem-oriented water quality investigations. The broad-scale national network will continue to play a role in the establishment of priorities for detailed investigations and as a first-level assessment of problems.

As the number of water users within a river basin increases, not only do water demands increase but so do the number and kinds of pollutants. Although progress has been made in reducing the entry of many pollutants into the environment, the rapid proliferation of

man-made and relatively non-degradable compounds (toxic materials) and the nature of their disposal make control extremely difficult. The Department of the Environment is aware of the fact that all environmental media (sediments, water and biota) are essential elements of the ecosystem and therefore is defining monitoring programs that will measure progress toward restoring and maintaining ecosystem integrity. Simply reporting "not detected" values for hazardous compounds in the water medium does not provide a sufficient environmental safeguard. It is necessary to include all media in the river basin monitoring programs to ensure that the aquatic environment is protected and enhanced for present and future water users.

The information obtained from such multimedia monitoring programs will be used to develop water quality criteria needed to support given water uses. These criteria are expressed as desirable or acceptable limits of concentration of various substances in water, sediment or biota. Based on these criteria, water quality objectives are then established for individual river basins. These water quality objectives provide a means of implementing effective water quality management by establishing limits which, if not exceeded, protect designated downstream uses.

The Department of the Environment is presently working in conjunction with various federal, provincial and foreign agencies to provide sound ecological information on such questions as eutrophication, the toxic and carcinogenic properties of toxic substances, the present health of the aquatic ecosystem and long-term trends. Only through sound water quality information obtained from many sources can our environmental problems be resolved.

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D.H. Cullen, Atlantic Region

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